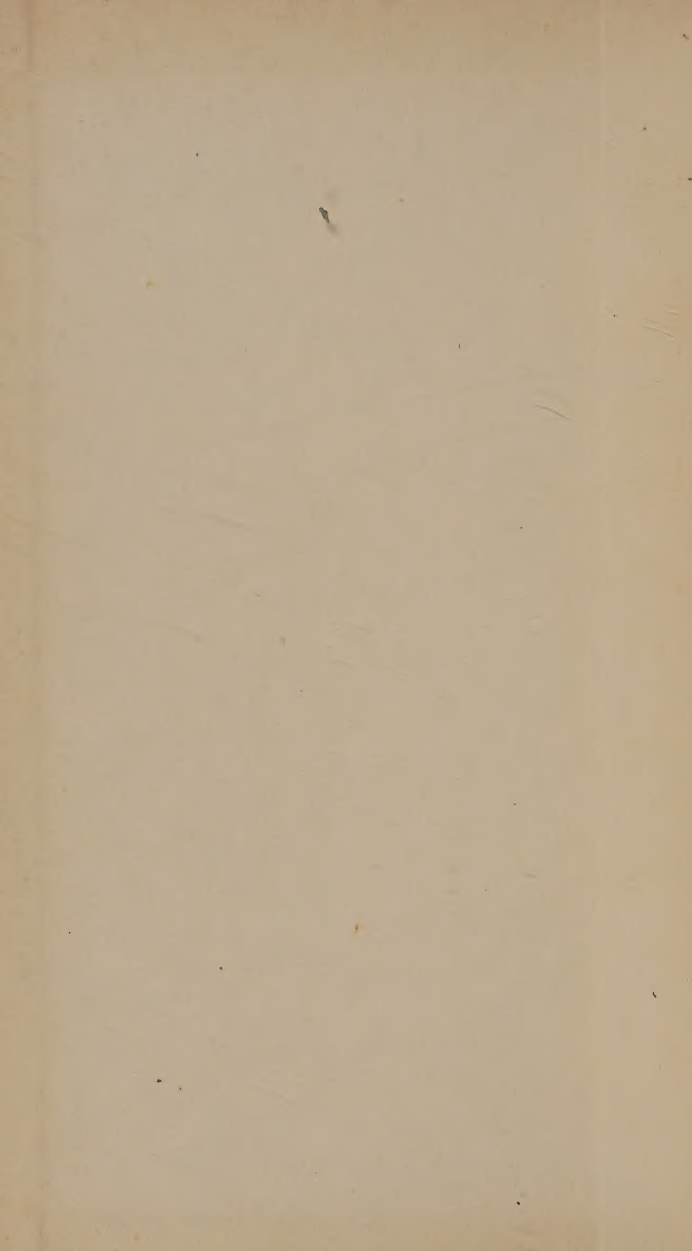




of
8-

MAY 21 1953



FIELD ENGINEERING

A Handbook of the Theory and
Practice of Railway Surveying,
Location and Construction

BY
WILLIAM W. BARNES, C.E.

FIELD ENGINEERING

EDITED BY
ROBERT CHAPMAN, C.E.

OF THE NEW YORK CENTRAL RAILROAD

REVISED EDITION

BY
PHILIP ALBMAN, C.E.

Professor of Civil Engineering
University of California

Volume I. 1253

OF THE THEORY

AND PRACTICE

OF RAILWAY ENGINEERING

NEW YORK: JOHN WILEY & SONS, 15

East CHAPMAN & HALL, LONDON

FIELD ENGINEERING

FIELD ENGINEERING

A Handbook of the Theory and
Practice of Railway Surveying,
Location, and Construction

by

WILLIAM H. SEARLES, C.E.

Late Member American Society of Civil Engineers
and

HOWARD CHAPIN IVES, C.E.

Late Civil and Consulting Engineer

TWENTY-SECOND EDITION

by

PHILIP KISSAM, C.E.

Professor of Civil Engineering
Princeton University

Volume I. TEXT

GEO. B. L. THORNTON

RT. 1 - BOX M-73

GUERNEVILLE, CALIF.

NEW YORK • JOHN WILEY & SONS, INC.

LONDON • CHAPMAN & HALL, LIMITED

COPYRIGHT, 1880
BY JOHN WILEY & SONS
1880 COPYRIGHT RENEWED 1908

COPYRIGHT, 1915, 1919
BY WILLIAM H. SEARLES
AND
HOWARD CHAPIN IVES
1915 COPYRIGHT RENEWED 1942
1919 COPYRIGHT RENEWED 1946

COPYRIGHT, 1925, 1929
BY MARY D. SEARLES
AND
HOWARD CHAPIN IVES

COPYRIGHT, 1936
BY HELEN SEARLES MCLEOD
AND
HOWARD CHAPIN IVES

COPYRIGHT, 1949
BY JOHN WILEY & SONS, INC.

All Rights Reserved

*This book or any part thereof must not
be reproduced in any form without
the written permission of the publisher.*

TWENTY-SECOND EDITION
Second Printing, June, 1950

PRINTED IN THE UNITED STATES OF AMERICA

PREFACE TO THE TWENTY-SECOND EDITION

IN PREPARING this edition, it has been the author's aim to clarify the text and to bring it up to date. Detailed instructions have been provided for various operations and new mathematical solutions have been developed. Many passages have been rewritten, over forty new illustrations have been added, and many pages of new material have been supplied.

The first chapter is new. It covers the fundamental principles of the economic location of railways and highways and outlines the entire location procedure. It is designed to show the part played by each operation covered in the book.

The new edition contains detailed directions for making a preliminary survey, completing the map, projecting a paper location, and establishing the tangents in the field. Specific steps are described for locating simple curves, compound curves, turnouts, and slope stakes, and for computing vertical curves, quantities, and haul diagrams.

The new material includes the two-base method for precise altimetry, a discussion of the advantages and methods of using air mapping, a new method of completing the compound curve theory which eliminates the need for "method II," the center-line method of staking out turnouts and yards, a new method of positioning turnouts on curved track, the complete theory of the vertical curve, an improvement in string lining, and a more precise statement of instrument adjustments.

The original text has been shortened by the removal of paragraphs devoted to elementary surveying in the belief that it can be better handled and to more purpose elsewhere.

PHILIP KISSAM

Princeton, N. J.
November 1948.

PREFACE TO THE NINETEENTH EDITION

As in the Seventeenth Edition the changes in this edition have been so extensive as to require a resetting of the entire text. These may be classified as follows: 1. Minor changes in the subject matter; 2. A rearrangement of certain portions of the book; 3. The omission of certain sections, and 4. The addition of a large amount of new material.

By careful selection, the net result of these changes has been to increase the size of the book by a few pages only. The needs of both the engineer in the field and the student have been kept in mind in the work of revision.

It is impossible to mention all the changes from the previous edition, but the following will indicate the more important items, following the notation above.

1. Every word, sentence, paragraph, section and chapter has been carefully considered with a view to improvement. A somewhat more open form of arrangement has been adopted in places, by the printer, thus tending to clarify. Where several methods of solution have been given, these have been separately numbered. The earlier editions of this book were noted for thoroughness of treatment and an aim has been made to live up to this reputation.

2. The chapters on Maximum Economy in Grades, etc., and that on Leveling have been placed towards the end of the volume. Some teachers do not give these chapters in connection with courses on Railroad Curves, and to practising engineers, this arrangement will make no material difference.

Old Chapter XVIII, Topographical Sketching, has been brought forward to form part of Chapter II, Preliminary Survey. Likewise, old section 156, on Templates and Paper Location, has been placed in the chapter on Location.

3. The Valvoid Curve has been omitted; likewise two or three problems of rare occurrence on Compound Curves.

Several engineers have told the reviser that they have been able to find the solutions of many special problems in this book, and nowhere else, consequently omissions have been most sparingly made.

4. Material additions have been made to the chapters on Reconnaissance, Preliminary Survey, Location, Simple Curves, Compound Curves, Reversed Curves, Turnouts and Crossings, Spirals, Cross Sections, Calculation of Earthwork, Haul and the Mass Diagram, and Track Laying.

It may be specially mentioned that more attention has been paid to: The Stadia Method of Preliminary Survey; to Forms of Field Notes; to the methods of locating a curve, where a set-up on the curve is necessary; and to Ladder Tracks. A somewhat more simple treatment of Compound Curves has been given, the original solution being retained as having great possibilities, and will be preferred by some. The use of the automatic slope rod and tape, and the cost of over-haul have been added.

The treatment of the American Railway Engineering Association Spiral was first given in the Eighteenth Edition. The method of solution is more or less original. Some of the tables for this curve are original.

For the Seventeenth Edition acknowledgments are made to: The American Railway Engineering Association for permission to use certain material as noted in the text; to the late A. M. Wellington's "Railway Earthwork," which was the first thorough treatment of Earthwork Diagrams; and to Mr. A. S. Crandon, for assistance on the illustrations and computations. Other acknowledgments in connection with the Tables are made in Preface to Volume II.

For the Eighteenth Edition to the American Railway Engineering Association for permission to use their form of spiral, and for Tables 46 and 49 from the Manual of Recommended Practice.

For the Nineteenth Edition to: The American Railway Engineering Association; Engineering and Contracting; to D. L. Hussey, for assistance on the illustrations; to Profs. W. B. Harris and Philip Kissam of Princeton University; to Prof. C. T. Bishop of Yale University; and to many teachers and engineers for kindly advice and criticism.

While extreme care has been exercised in proof reading both

the text and the tables, errors may be found to exist. Publishers and author will appreciate a prompt notification of any such.

In conclusion, the reviser would record the fact that he has seriously missed the guidance, help and inspiration of Mr. Searles in the work on the Nineteenth Edition.

H. C. I.

December 1924

Handwritten text, likely a signature or date, located in the upper left corner of the page.

PREFACE TO THE FIRST EDITION

ALTHOUGH the modern railway system is but about fifty years old, yet its growth has been so rapid, and the progress in the science of railway construction so great, as to render the earlier technical books on this subject inadequate to the needs of the engineer of to-day.

In the course of his practical experience as a railway engineer, the author was strongly impressed with the want of a more complete hand-book for field use, and finally concluded, at the solicitation of his friends, to undertake the preparation of the present volume.

The aim in this work has been:

First.—To present the general subject of railway field work in a progressive and logical order, for the benefit of beginners.

Second.—To classify the various problems presented, so that they may be readily referred to.

Third.—To embrace discussions of all the more important practical questions while avoiding matters non-essential.

Fourth.—To employ throughout the work a uniform and systematic notation, easily understood and remembered, so that after one perusal the formulas may be intelligible at a glance wherever referred to.

Fifth.—To express the resulting formula of every problem in the shape best adapted to convenient numerical computation.

Sixth.—To furnish a large variety of useful tables, more complete and extended than any heretofore published, especially adapted to the wants of the field engineer.

An elementary knowledge of algebra, geometry and trigonometry on the part of the reader has been taken for granted, as a command of these instrumentalities is deemed essential to the education of the civil engineer. The few references

to mechanics, analytical geometry, optics and the calculus may be assumed correct by those not conversant with these branches.

Many of the problems in curves are new, yet there is hardly one that has not presented itself to the author in the course of his practice. The investigation of the valvoid curve is original, and though the mathematical discussion is somewhat difficult, yet the resulting formulas taken in connection with Table VII, are exceedingly simple and convenient for the solution of a certain class of problems.

(The valvoid and Table VII have been omitted in the present edition.)

The treatment of compound curves is novel and exhaustive. A few general equations are established, which, by slight modifications, solve all the problems that can occur.

No discussion of reversed curves is given, because these are inconsistent with good practice, except in turnouts, under which head they are noticed.

The chapter on leveling includes a discussion of stadia measurements, with practical formulas. The chapter on earthwork contains a review of several methods for calculating quantities, and states the conditions under which these succeed or fail in giving correct results.

Among the tables, numbers 2, 3, 7, 26, 29, and 43 are original. The adoption of versed sines and external secants throughout the work, wherever these would simplify the formulas, rendered necessary the preparation of tables of these functions. The table of logarithmic versed sines and external secants has been computed from ten-place logarithmic tables of sines and tangents, so that the last decimal is to be relied on, and no pains have been spared to make the table thoroughly accurate.

Tables numbers 1, 4, 5, 6, 8, 9, 14, 22, and 30 have been recalculated, enlarged, and some of them carried to more decimal places than similar tables heretofore published. The intention has been to give one more decimal than usual, so that in any combination of figures the result of calculation might be reliable to the last figure usually required.

The tables which have been compiled and rearranged are numbers 15, 16, 17, 24, 25, 41, 42, and 44. The tables of log sines and tangents here given are the only six-place tables

which give the differences correctly for seconds. The table of logarithms of numbers is accompanied by a complete table of proportional parts, which greatly facilitates interpolation for the fifth and sixth figures.

In all the tables, whether new or old, scrupulous care has been taken to make the last figure correct, and the greatest diligence has been exercised by various checks and comparisons to eliminate every error. It is, therefore, hoped and believed that a very high degree of accuracy has been obtained, and that these tables will be found to stand second to none in this respect.

The preparation of this work has extended over several years, as time could be spared to it from other engagements. It is, therefore, the expression of deliberate thought, based on experience, and as such is submitted to the judgment of brother engineers. If it shall prove to have even partially met the aim herein announced, and so shall serve to smooth the way of the ambitious student, or to assist the expert in his responsible duties, the labors of the author will not have been in vain.

WM. H. SEARLES, C.E.

NEW YORK, March 1st, 1880.

THE
OF THE
AND

THE
OF THE
AND

THE
OF THE
AND

CONTENTS

CHAPTER I

THE LOCATION OF A TRANSPORTATION LINE

PRELIMINARY CONSIDERATIONS		PAGE
SECTION		
1. The decision to build and the inception of the location procedure		1
2. Location procedure		1
RAILROAD LOCATION		
3. Railroad location outlined		2
4. The cost of hauling traffic		2
5. The steps in the solution of a railroad location problem		3
HIGHWAY LOCATION		
6. Highway location outlined		5
SCOPE		
7. The scope of the problem		6

CHAPTER II

RECONNAISSANCE

8. Reconnaissance	7
9. Conclusion	8
10. Reconnaissance for area	8
11. Reconnaissance along a watercourse	8
12. Reconnaissance crossing the general direction of the drainage .	9
13. Reconnaissance for a mountain route	10
14. Reconnaissance for line	10
15. Reconnaissance instruments	11

BAROMETRIC LEVELING

16. The altimeter	12
17. The relation between barometric pressure and altitude	13
18. The calibration of an altimeter	14
19. Field corrections	14

SECTION	PAGE
20. Changes in barometric pressure	14
21. Wind	15
22. The two-base method	15

FIELD ALTIMETRY

23. Field procedure for barometric leveling	16
24. The two-base method	16
25. Instrument corrections	17
26. Illustrative example	17
27. The one-base method	18
28. Single-altimeter method	18

CHAPTER III

THE PRELIMINARY SURVEY AND PROJECT- ING LOCATION

29. A preliminary survey	19
30. Preliminary survey procedure	19
31. The traverse	20
32. Accuracy	20
33. Angle measurement	20
34. Distance measurement	22
35. The profile	22
36. Topography	23
37. Procedure for finding contours	23
38. Topographical features included	24
39. Organization of corps of engineers	24

THE TRANSIT PARTY

40. The locating engineer	26
41. The transitman	26
42. The head chainman	27
43. The rear chainman	28
44. The axeman	28
45. The stakeman	28

THE LEVEL PARTY

46. The leveler	28
47. The rodman	29

TOPOGRAPHY

48. The topographer	29
49. Contours	30
50. Detailed information	30

SECTION	STADIA METHOD	PAGE
51.	Transit and stadia	31

TOPOGRAPHICAL SKETCHING

52-55.	Methods of topographical sketching	31
--------	--	----

AERIAL MAPPING

56.	The use of aerial mapping	34
57.	The process of aerial mapping	34
58-59.	The Multiplex Projector method	35
60.	Accuracy	38
61.	The procedure for using air mapping in location	38
62.	Other advantages of aerial mapping	39

CONSTRUCTING THE MAP

63.	Procedure for constructing the map	40
-----	--	----

PROJECTING LOCATION

64.	Projecting a paper location	41
65.	Scope	41
66.	Fixing grade lines	41
67.	The grade contour	43
68.	Establishing the preliminary location line on the map	45
69.	Radius of curvature	45
70.	Separation between curves	45
71.	Plotting the line	45
72.	Data for the location survey	46

CHAPTER IV

THE LOCATION SURVEY

73.	Staking out the tangents	48
74.	Field procedure for location	48
75.	Contract drawings	50
76.	Construction	51

CHAPTER V

SIMPLE CURVES

ELEMENTARY RELATIONS

77.	A simple curve	52
78.	Degree of curve	52
79.	Stationing on curves	54

SECTION	PAGE
80. The central angle	55
81. The vertex or point of intersection	56
82. The length of curve	56
83-84. Subchords	57
85-88. Definitions of other elements	60
89. The elements usually known	60
90. Tangent distance in terms of radius and central angle	60
91. Long chord in terms of radius and central angle	61
92. Middle ordinate in terms of radius and central angle	62
93. External distance in terms of radius and central angle	62
94. Elements sometimes known	63
95. Radius and degree in terms of T and Δ	63
96. External distance in terms of T and Δ	64
97. Radius and degree in terms of E and Δ	65
98. Tangent distance in terms of E and Δ	66

LOCATION OF CURVES BY DEFLECTION ANGLES

99. Geometric principles	66
100. The 12 steps followed in staking out a curve by deflection angles	66

WHEN A SETUP ON THE CURVE IS NECESSARY

101. Geometry	71
102. Procedure	73
103. Method by deflection angles only	74
104. Metric curves	74
105. Relining an existing curve	75

LOCATION OF CURVES BY OFFSETS

106. Methods listed	76
-------------------------------	----

TO LOCATE A CURVE BY OFFSETS FROM THE CHORDS PRODUCED

107. When the curve begins and ends at a station	76
108-110. When the curve begins and ends with a subchord	77

TO LOCATE A CURVE BY OFFSETS FROM THE TANGENTS

111. When the curve begins at a station	79
112. When the curve begins with a subchord	80

TO LOCATE A CURVE BY MIDDLE ORDINATES

113. When the curve begins and ends at a station	81
114. When the curve begins or ends with a subchord	81

TO LOCATE A CURVE BY ORDINATES FROM A LONG CHORD

115-118. When the curve begins and ends at a station	82
119. When the curve begins or ends with any subchord	85
120. Right angles by linear measurement	87

OBSTACLES TO THE LOCATION OF CURVES

SECTION	PAGE
121. P.I. inaccessible	87
122. P.C. inaccessible	88
123. P.I. and P.C. inaccessible	92
124. To pass from a curve to the forward tangent when the P.T. is inaccessible	93
125. To pass an obstacle on a curve	93

SPECIAL PROBLEMS IN SIMPLE CURVES

TANGENTS REMAINING IN SAME POSITION

126. Change in R and E for an assumed change in T	94
127. Change in R and T for an assumed change in E	95
128. Change in T and E for an assumed change in R	96
129. Other relationships	97
130. To change the P.C. so that a curve of the same R may end in a parallel tangent	97
131. To find the R of a curve that, from the same P.C., will end in a parallel tangent	97
132. To change the R and the P.C. so that the new curve may end in a parallel tangent directly opposite the old P.T.	99
133. To find the new P.C. and P.T. after each tangent has been moved parallel to itself	100

CHANGE IN DIRECTION OF FORWARD
TANGENT

134. To find new R and P.C. for new tangent at same P.T.	102
135. To change P.C. for new tangent from same P.I.	103
136. To find new R for new tangent from same P.I.	103
137. To find new R and P.C. for same E , but new Δ	103

TO PASS A CURVE THROUGH A GIVEN POINT

138. Point located by plus and offset	104
139. Point located by a radial offset	105
140. Point located by angle and distance from P.I.	108

MISCELLANEOUS PROBLEMS

141. To find a tangent through a distant point	110
142. To find a tangent to two curves	111
143. To find a tangent to two curves reversed	113
144. The traverse method	115

CHAPTER VI

COMPOUND CURVES

THEORY

145. Definition of compound curve	116
146. Combinations of given quantities	116

SECTION	METHOD OF TREATMENT	PAGE
147.	Given: $R_1, R_2, \Delta_1, \Delta_2$; required Δ, T_1, T_2	117
148-149.	General equations	118
150.	Given: $R_1, R_2, \Delta_1, \Delta_2$; required Δ, T_1, T_2	119
151.	Given: Δ, T_1, T_2 , and R_1 or R_2 ; to find Δ_1, Δ_2 , and R_2 or R_1	120
152.	Given: AB, VAB, VBA , and R_2 or R_1 ; to find Δ_1, Δ_2 , and R_1 or R_2	120
153.	Given: R_1, R_2, Δ , and T_1 or T_2 ; to find the other tangent and Δ_1, Δ_2	121
154.	Given: Δ , one tangent, and the radius and central angle of adjacent arc; to find other radius and tangent	121
155.	General equations	122
156.	Given: $T_1, T_2, \Delta_1, \Delta_2$; to find Δ, R_1, R_2	123
157.	Given: a radius, a nonadjacent tangent, and the central angles; to find the other radius and tangent	123

FIELD WORK

158.	The usual field procedure	123
159.	To locate a compound curve when the P.C.C. is inaccessible	125

SPECIAL PROBLEMS IN COMPOUND CURVES

160.	To compound a simple curve so that it will end in a given parallel tangent	127
161.	New P.C.C., same last radius, but parallel last tangent	129
162.	New P.C.C., new last radius for P.T. on parallel tangent opposite old P.T.	131
163.	New last radius, new P.C.C., same tangents	134

THREE-CENTERED COMPOUND CURVES

164-165.	To replace a simple curve by a three-centered compound curve with same tangent points	136
166.	To replace a simple curve by a three-centered compound curve through same middle point	139
167.	To replace a tangent by a compound curve	143
167a.	The traverse method	148

CHAPTER VII

REVERSED CURVES

168.	Definition	149
------	----------------------	-----

PARALLEL TANGENTS

169.	Given: p, r ; to find Δ_r	149
170.	Given: p, r_1, Δ_r ; to find r_2	150
171.	Given: p, d, r_1 ; to find r_2	151

DIVERGING TANGENTS

SECTION	PAGE
172. Given: l , Δ_1 , Δ_2 ; to find r_1	152
173. Given: l , Δ_1 , Δ_2 ; to find r	153
174. Solutions simplified by field measurement	153
175. Given: Δ , P.C. to V , r_1 , r_2 ; to find Δ_1 , Δ_2 , and V to P.T. . .	154
176. Given: Δ , r_1 , r_2 , and P.T. to V ; to find Δ_1 , Δ_2 , and P.C. to V .	154
177. Given: r_1 , r_2 , to change P.R.C. to end in a parallel tangent . .	155

CHAPTER VIII

TURNOUTS AND CROSSINGS

TURNOUTS

178. Gauge	157
179. Definition of turnout	158
180. The frog	159
181. Rails in a turnout	161
182. Leads	161
183. Split switch	161
184. To increase the lead	163
185. To decrease the lead	165
186. Double turnouts	165
187. Stub switch	167
188. Offsets for constructing turnouts	169

FIELD PROCEDURE FOR ESTABLISHING A TURNOUT

189. Standard turnout data	171
190. Choice of frog	172
191. Methods of determining the position of the frog	172
192. The elements of a turnout	172
193. Procedure for laying out a turnout	175
194. Methods of locating point A	175

TURNOUTS FROM STRAIGHT TRACK

195. Turnout to a siding	175
196. Turnout to a siding, approximate method	177
197. Cross-overs and connecting tracks	178
198. Coordinates for cross-overs	179
199. Cross-over by a straight track	179
200. Cross-over by a simple curve connecting different frogs on parallel straight tracks	179
201. Connecting track by a simple curve connecting nonparallel straight tracks	180
202. Connecting track by a simple curve between frogs in place . .	182
203. Cross-over by a reversed curve connecting parallel straight tracks	182

SECTION	PAGE
204. Connecting track by a reversed curve between nonparallel straight tracks	184
205. Turnout from a straight track to a parallel side track	186
206. Yard tracks	187
207. Computation of track positions in yards	189
208. Coordinates	192

TURNOUTS FROM CURVED TRACKS

209. The location of frogs on curved tracks	192
210. To convert formulas for method I to formulas for method II .	195
211. Data for method I	195
212. Turnout from curved main track to a siding	196
213. Turnout from a curved main track to a parallel siding	202
214. Cross-over by a simple curve connecting parallel curved tracks	206
215. Cross-over by a reversed curve connecting parallel curved tracks	208
216. Field procedure for laying out a cross-over between two parallel curved tracks when the tracks are in place	210
217. Connecting track that reverses direction	210
218. Wyes	212
219. Symmetrical wye on straight main track	212
220. Symmetrical wye on curved main track	213

CROSSINGS

221. Crossing of one straight and one curved track	214
222. Crossing of two curved tracks	216
223. Slip switches	216

CHAPTER IX

THE SPIRAL CURVES

THE SEARLES SPIRAL

224-225. Principles	219
226. Spiral deflections	220
227. To adapt the spiral to practical requirements	222
228. To find the spiral long chord	222
229. Values of p and q	224
230. Combination of curve and spiral	224
231. To find the external distance	225
232. The change in R' for a change in π	226
233. To replace a simple curve by another with spirals on the same ground	227
234. To replace a simple curve by another with spirals that shall pass through the same middle point	228
235. To compound a simple curve to introduce spirals	229
236. To move a curve inward to provide for spirals	231

SPIRALS WITH COMPOUND CURVES

SECTION	PAGE
237. To move a compound curve inward to provide for spirals . . .	233
238. To replace a compound curve by another with spirals on the same ground	234
239. To introduce a spiral between the arcs of a compound curve .	236

FIELD AND OFFICE WORK

240. Field procedure	238
--------------------------------	-----

THE TEN-CHORD SPIRAL

241. The ten-chord spiral	240
242. Notation	240
243-248. Formulas	241
249-251. Field methods	246
252. Choice of spirals	249
253. To introduce the spiral in a compound curve	249
254. A.R.E.A. notation	250

CHAPTER X

CROSS SECTIONS

STANDARD METHODS

255. Field measurements for earthwork	251
256. Shape of cross sections	252
257. Plotting cross sections	253

SLOPE STAKING

258. Procedure for setting slope stakes	254
---	-----

CROSS SECTIONS FROM SLOPE-STAKE NOTES

259. Field procedure	257
260. Complete field notes	257
261-262. Sidehill section	258
263. Terminal sections	259

OTHER FIELD METHODS

264. By equation based on ground slope	261
265. By use of automatic rod and tape	261
266. Form of field book	263

CHAPTER XI

CALCULATION OF EARTHWORK

267. The principles involved	266
268. Methods of computing the areas of cross sections	267
269. Formulas for sectional areas	269

SECTION	PAGE
270. Three-level section	270
271. Five-level section	271
272. Irregular section	271
273. Sidehill sections	272
274. Valuation work	272
275. Volumes of solids	273
276. Prismoidal correction formulas	274
277. Application of the prismoidal correction	277
278. Correction of earthwork for curvature	278
279. Isolated masses	283
280. Borrow pits	283
281. Vertical prisms	284
282. Volumes of truncated triangular prisms	284
283. Volumes of truncated rectangular prisms	285
284-285. Method by unit areas	286

CHAPTER XII

EARTHWORK TABLES

286. Purpose of tables	288
287. Level sections	288
288. Tables of triangular prisms	289
289. Tables of three-level sections	289
290. Tables for irregular sections	290
291. Prismoidal correction table	290
292. Example	291

CHAPTER XIII

EARTHWORK DIAGRAMS

293. General principles	294
294. Triangular prisms	295
295. Use of the diagram	296
296. Diagram for three-level sections	296
297. Use of the diagram	299
298. Diagram for prismoidal corrections	299
299. Use of the diagram	300
300. Conclusion	301

CHAPTER XIV

HAUL AND THE MASS DIAGRAM

HAUL

301. Haul	302
302. Economy of earthwork from the profile and cross sections	303
303. Quantity profile	304

THE MASS DIAGRAM

SECTION	PAGE
304. The mass-haul diagram	305
305. Construction of a mass-haul diagram	305
306. Payment of overhaul	308

THE USE OF THE MASS DIAGRAM

307. Example of the use of the mass diagram	309
---	-----

CHAPTER XV

CONSTRUCTION

308. The engineering department	312
309. Clearing and grubbing	312
310. Test levels	313
311. Cross sections	313
312. Shrinkage	313
313. Alteration of line	315
314. Drains and culverts	315
315. Arch culverts	317
316. Staking out foundation pits	317
317. Cattle guards	322
318. Trestlework	322
319. Tunnels	324
320-321. Retracing the line	330

ESTIMATES

322. The final estimate	331
323. Monthly estimates	331

CHAPTER XVI

TRACK LAYING

LINE AND GRADE

324. Introduction	334
325. Center-line stakes	334
326. Curving rails	334
327. The middle ordinate in terms of D	335
328. The middle ordinate for any chord in terms of the chord and the radius	335
329. Testing track curvature	337
330. Grade stakes	338
331. Raising track	338
332. Rate of grade	339
333. Grade line	339

THE Y LEVEL	
SECTION	PAGE
396. Adjustment of the Y level	398

THE DUMPY LEVEL

397. Adjustment of the dumpy level	399
--	-----

CHAPTER XXI

HIGHWAY CURVES

SIMPLE CURVES

398. Highway practice	401
399. Parts of a simple curve	401
400. General formulas	401

CURVE TABLES

401. Value of the radius	402
402. Value of tangent	402
403. Values of C , M , and E	402
404. The arc definition	403
405. Length of curve	403
406. Example	404
407. Field work	405
408. The approximate arc method	405
409. The chord method	405
410. Where the radius is selected	405
411. Location of curve	406
412. Continuous stationing	406
413. Equal parts	408
414. Final subchord	408
415. Choosing even deflections	408
416. Comparison of different methods	409
417. Selection of the tangent distance	409
418. Field work	409
419. Comparison between highway curve and railroad curve for the same Δ and numerical value of D	410
420. The traverse method	410

COMPOUND AND REVERSED CURVES

421. Differences in highway curves	410
--	-----

SPIRALS

422. Difference in highway curves	413
---	-----

CHAPTER I

THE LOCATION OF A TRANSPORTATION LINE

PRELIMINARY CONSIDERATIONS

1. The decision to build and the inception of the location procedure. The most important question, when the construction of a transportation line is considered, is whether or not to build the line at all. This can sometimes be answered by a short investigation of general conditions; sometimes the answer must await the completion of part of the engineering surveys, and sometimes it cannot be answered until the construction is actually under way. When an investigation indicates a possibility that the line should be built, the location procedure is commenced. It is continued until the line is completed and in operation, unless stopped at any time by the exhaustion of available funds or by the accumulation of data that indicate that the costs will outweigh the advantages.

2. Location procedure. The object of the location procedure for a transportation line is, of course, to find a route that will bring the greatest return for the minimum over-all expenditure. The method used is much the same, however questionable or obvious the advantages of the project may appear and whatever type of transportation service is involved. The same location methods can be applied to a railroad, a highway, a pipe line, a canal, or nearly any other type of transportation. Owing to the extensive use and rigid requirements of railroads and highways, the art of location has been perhaps more highly developed for them than for the other types. The techniques used for them, therefore, have come to be recognized as models for other types, and they are easily adapted to the particular type required.

Railroad and highway location methods parallel each other until the subgrade is ready for the track or pavement. Even at this point they differ only in form. Although track align-

ment must be more nearly perfect than pavement alignment, track may be continually adjusted, whereas pavement must be placed permanently, and accordingly equal care is usually given to both. Track accessories, such as switches, sidings, cross-overs, and yards, add further details to railroad location not required for highways, but complicated highway intersection designs present the same type of difficulties as railroad track problems, and they are solved by the same methods, in fact, by nearly the same formulas.

RAILROAD LOCATION

3. Railroad location outlined. The basic problem of railway location is the selection of two termini between which at least sufficient traffic will flow to pay for the railroad service and to earn a profit. Second in importance is the choice of as many major way points as can be found which will materially increase the traffic volume. The engineer's chief problem is to find a route, connecting as nearly as possible the centers of population of these termini and way points, over which a railroad can be built that will carry the expected traffic. His choice of route must be such that the interest on the investment plus the cost of operation will be a minimum and the total cost of building the railroad and of inaugurating service will not exceed the available funds.

In his choice of the **route**, the engineer directly controls the cost of the acquisition of right of way and the cost of construction. In his choice of **rates of grade**, the engineer controls the cost of hauling traffic. As the cost of construction must usually be increased in order to reduce the cost of hauling traffic, and vice versa, the engineer is continually required to make economic comparisons between the advantages of each. The costs of property acquisition and of construction vary directly with quantity. The cost of hauling traffic obeys the rather unusual laws outlined in the next section.

4. The cost of hauling traffic. The cost of hauling traffic is almost directly proportional to the **number of trains** required. Accordingly, the longer the trains, the less the operation costs. Train resistance is, therefore, of great importance. The values of the main sources of train resistance are given

here in approximate per cents of the weight of the train:

1. Friction of rolling stock	0.3%
2. Curve resistance per degree	0.04%
3. Grade resistance	Equal to the rate of grade

For example, if a train were moving on a 5° curve (radius 1150 ft, see Table I in Part II) and up a 1.5% grade, the resistance per ton would be the following:

1. Friction of rolling stock	6 lb
2. Curve resistance	4 lb
3. Grade resistance	30 lb

Note. This subject is covered fully in Chapter XVIII.

It is clear that the one section of track where the combined curve and grade resistance is maximum will control the length of trains for the entire engine stage. As such a section is usually on a grade, it is called the **ruling grade**. It is also clear that the other curves and grades on the engine stage have little effect on the cost of operation. It is true that the combined effect of these minor resistances increases the cost of operation, but their effect is slight in comparison with that of the ruling grade.

The topography, of course, generally controls the ruling grade. But, by proper selection of route, some steep grades can be eliminated, and others can be collected in one section of the line where a pusher engine can be used economically. Isolated steep grades or sharp curves whose high resistance might limit the length of trains should be avoided. They can nearly always be eliminated by slight changes of route or by additional cut or fill. Extra expenditures of this sort are usually not only justified but are essential.

5. The steps in the solution of a railroad location problem. A location problem is always solved by successive approximations. The procedure is indicated by the steps listed below. They are usually followed where the topography chiefly controls the location. In easy country where the problem is very simple, in densely populated areas where the position of the line is rigidly controlled by property values, or where very few possible locations exist, the process can be much curtailed and several of the steps listed can be combined.

1. **The termini** are selected.
2. A **reconnaissance of area** is made to discover the possible way points and all possible routes.
3. A **reconnaissance of line** is made along the possible routes to determine which offers the greatest advantages. The results of this survey determine the general route and the ruling grades and, therefore, indicate the line for which an accurate map must be made. The data obtained must include the approximate elevations and the approximate distances between governing points, which are points that can be connected by uniform grades.
4. **The preliminary survey**, which follows, must result in a strip map so placed that its center lies as nearly as possible along the center line of the final location. The engineer is guided in the details of his choice of the strip of ground to map by the uniform grade established by the reconnaissance for line. He follows ground that rises or falls at the predetermined uniform grade. The map usually includes 5-ft contours, property lines, highways, streams, and all items that affect the cost of construction.
5. **Paper location.** After the positions and elevations of the governing points are established on the strip map, the **grade contour** is drawn. A grade contour is a line which follows the uniform grade along the ground surface represented. To this is fitted a series of circular arcs and straight lines which represent the **curves** and **tangents** of the projected center line of the railroad. By fitting them as closely as possible to the grade contour, a location is obtained that has nearly a minimum of cut and fill.
6. **The preliminary location survey** consists of establishing true tangents and curves on the ground where indicated by the projected location on the map. By careful field measurements based on this line, the quantities of cut and fill are determined.
7. **The final location survey** consists of adjusting the location line so as to reduce cut and fill and other items of cost.
8. **Construction.** The engineer gives line and grade in detail for *construction*. He must see that the work is completed according to plan, and he must measure the work completed each month to determine the monthly payments to the contractor.
9. **Track.** Finally, the **track**, including main line, switches, and yards, is staked out and built.

HIGHWAY LOCATION

6. Highway location outlined. The basic problem of highway location is to recognize a route where present highway facilities are inadequate. Various types of traffic censuses are one of the means to this end. Actual traffic counts and origin-destination surveys are essential. The justification for the new highway and the type to be constructed should usually be based on the value of the estimated vehicle-hours and vehicle-miles saved per year. Although the point is highly debatable, it is here assumed that the general increase in real estate values, the net improvement to near-by real estate, the social advantages, the scenic values, the net direct and indirect taxes gained by the state, and other economic effects of highways are, in the long run, measurable in the actual use of the highway by vehicles. To compute the savings the estimated *future* number of vehicles should be used, and the estimated time and distance over the new route should be compared to that of any existing means of making the same trip.

The vehicular speed desired and the probable volume of traffic determine the details of design. These include the arrangement of traffic lanes and shoulders, sight distances, maximum degrees of curvature, maximum grades, and devices used for crossings and interchange.

The engineer's chief problem is to find a route over which such a highway can be built with the funds available. The choice of route must be decided by a comparison between the savings due to reduced distance and time of travel and the extra costs of interest and maintenance.

Since highway vehicles can traverse 4% grades with little reduction in speed and can negotiate 7% grades safely except in unusually bad weather, grades are of much less consequence in highway than in railway location. Also, in highway operation, there is nothing comparable to the railway ruling grade. Accordingly, except to avoid driver surprise, there is no economic advantage in grouping steep grades in one locality. The chief criterion for the selection of curves and grades is the comparison between the cost of reducing the curvature or the rates of grade and the value of the vehicle-hours and vehicle-miles saved by such a change.

Owing to the flexibility in the use of grades, the location of a highway is frequently decided by the cost of right of way. A large proportion of highways, therefore, must follow old roads with only minor changes in alignment. In these instances, the location is simplified in general although it is complicated in detail. It is often possible, therefore, to combine several of the nine steps described for railway location. For example, reconnaissance for area and reconnaissance line are often cursory—a mere choice between existing routes, the preliminary survey can be omitted, and the map data can be surveyed from the preliminary location line. On the other hand, any necessary change in alignment often requires a much more detailed survey and a more careful estimate of cost than an entirely new location, as it frequently involves the purchase of more expensive real estate and the construction of exceptionally costly facilities.

When a highway is laid out over a new route where land values are comparatively low, the location procedure is nearly the same as that for railroads.

SCOPE

7. The scope of the problem. It is evident from the foregoing paragraphs that the successful location of a transportation line is a grave and difficult problem requiring a fundamental understanding of economics, a thorough knowledge of the type of transportation to be located, complete data on possible revenues and costs, and many years' experience in the operation of similar systems. It has been outlined here not as a text for the locating engineer but in order to demonstrate the relation of field practice, which is covered in this text, to the general location problem.

CHAPTER II

RECONNAISSANCE

8. Reconnaissance. The reconnaissance survey is by far the most important part of location engineering. On it depends whether or not the best line is discovered. The loss occasioned by the selection of the second best route may reach large figures, cause the failure of the railroad, or prevent the completion of the highway. The reconnaissance must, therefore, be performed by the chief engineer *in person*. At the outset the engineer must collect all the topographic data available for the area in question. These include existing maps, survey control, aerial photographs, land values, and evidence from persons familiar with the area. He must make a rough survey of the area himself, become familiar with the arrangement of the drainage system, and know the position and elevation of every saddle that might provide a connection between one drainage system and the next. Even if good maps and aerial photographs are available, it is often desirable to prepare a map on a scale of 1 or 2 in. to a mile, on which are drawn the principal features of the country to be traversed, such as streams, roads, towns, and the principal ridges, if known, but on which the further details are left to be filled in by the engineer as he progresses. Such a map furnishes a correct scale for his sketches, and saves much valuable time, as he has only to sketch what the map does not contain, and occasionally make corrections when he finds the map to be in error. He also notes on the map the *governing points* of the route, such as the best crossings of streams, ridges, or other roads, and any point where the line will evidently be compelled to pass. He may then indicate the route by a dotted line on the map drawn through the governing points. Having traversed the route in one direction, he should retrace his steps, verifying or correcting his observations, and making

such further notes as seem important. In a densely wooded country with but few openings it may be impossible for him to get a commanding view from any point that will afford him the necessary information as to the general topography. He must then depend largely on instrumental observations, taking these more frequently and noting carefully all details likely to prove useful in future surveys.

Country such as swamps and thickly wooded districts, which are physically difficult to traverse, may unduly prejudice the observer in his conclusions. He should remember that construction will eliminate these inconveniences.

The engineer should not only *seek the best ground* on the route first assumed, but also have an eye open to all other possible routes, holding them in consideration pending this accumulation of evidence, and being ready, finally, to adopt that one which promises the *greatest ultimate economy*. He should be able to read the face of the country like a map, and to carry in his mind a continuous idea or image of any line he is examining, so as to judge with tolerable accuracy the influence any one portion of the line may have on another as to alignment and grade, even though many miles apart. In the successful prosecution of a reconnaissance he must depend mainly on his own natural tact and a judgment matured by experience.

9. Conclusion. The reconnaissance furnishes information for the general direction which the proposed line of road will take, with an idea of the length of line and the probable grade. Any serious mistake which is made in reconnaissance will be difficult to remedy as time goes on.

The reconnaissance survey can be divided into two parts, reconnaissance for area and reconnaissance for line.

10. Reconnaissance for area. Reconnaissance for area has three forms, as follows:

1. *Reconnaissance along a watercourse.*
2. *Reconnaissance crossing the general direction of the drainage.*
3. *Reconnaissance for a mountain route.*

11. Reconnaissance along a watercourse. A line running *along a watercourse* is most easily located. In this case the choice is to be made merely between the two banks of the

stream or between keeping to one bank continuously and making occasional crossings. When the stream is small, it will usually be found best to cross it at intervals, the advantage of direct alignment outweighing the cost of bridging; when the stream is of considerable size, the solution of the problem is not so obvious, but requires a thorough comparison of results in the two cases to determine whether it should be crossed or not. In the case of the larger rivers, crossing may be out of the question.

When there is a choice of sides, the engineer should traverse both banks on reconnaissance, and, while examining the one side in detail, he should take a general and comprehensive view of the other. Only thus can he gain a complete knowledge of either side. The points to be considered are the relative value of the property on either side, the number and size of tributary streams and the probable cost of crossing them, the cost of earthwork as affected by the amount and character of the material to be removed and the liability to landslides, the amount and degree of curvature required, and the probable revenues which the road can command. If after these points have been considered one bank of the stream appears to be more advantageous all the way, the solution to the problem is obvious. If, however, the greater advantages are found on either bank alternately, as usually happens, the propriety of bridging the stream, along with the costs and advantages, must be considered as an additional factor.

In selecting stream crossings, the engineer should consider not only the height of the bank but also the character of the bottom, its suitability for foundations, and its liability to be washed by the current. He should observe the direction and force of the current and its behavior during freshets and ascertain the extremes of high and low water if possible. An approximate estimate of the cost of bridging may be made. Where the located line follows the meandering of a stream more or less closely, it is called a *valley line*.

12. Reconnaissance crossing the general direction of the drainage. When no watercourse exists along which the road may be located, the difficulties of selecting a route are increased, and these usually become greatest when the streams are found to run about at *right angles to the direction of the road*. Valleys and ridges are to be crossed alternately, which in-

volves the necessity of ascending and descending grades, diverts the road from a straight line, and increases the distance and curvature. The engineer must seek the lowest points on the ridges and the highest banks at the stream crossings, in order to *reduce* as much as possible the *total rise and fall*, but these points must be so chosen that they may be connected by a grade not exceeding the maximum which may be allowable. The intervening country between summit and stream must usually be carefully examined, even on reconnaissance, to determine where the assumed grade will find sustaining ground at a reasonable expense for earthwork and right of way. A line located thus is called a *cross-country line*.

13. Reconnaissance for a mountain route. In mountainous country it is often difficult to project a line in an absolutely forward direction. In such a case, one of three devices must be used.

(a) There must be an increase in length of line so as to reduce the ruling grade. This is called "development." At many points the direction traversed may be directly opposite to the general direction of the route.

(b) *Switchbacks* may be employed. Here the train after proceeding a certain distance is stopped, a switch is thrown behind it, and the train is backed up a branch of the switchback. A second switch is then thrown in front of the train, and a forward movement is made along another branch of the switchback. These backward and forward movements alternate until the desired elevation is reached.

(c) In the process of development it is sometimes necessary for the line in doubling back to cross itself at a different level. To accomplish this a bridge or a tunnel may be used. Such a location is a "loop" or a "spiral."

14. Reconnaissance for line. After the reconnaissance for area has been completed, it may then be necessary or desirable to obtain more accurate information of one or more narrow belts of country. This may be termed **reconnaissance for line**. The most important point in the location of any road is the grade which can be obtained. The possible grade depends on the length of line and the difference in elevation of the termini. In order to find the distance between the termini, the directions and lengths of the various courses must be measured.

15. Reconnaissance instruments. Certain hand instruments are used for reconnaissance. They are the following:

1. The prismatic compass.
2. The passometer, pedometer, or odometer.
3. The pedograph.
4. The hand (or Locke) level.
5. Field glasses or a telescope.
6. The aneroid barometer (or altimeter).
7. Portable astronomical instruments (occasionally used in unsettled country).

The **prismatic compass** is a portable instrument with folding sights, with which the bearing to an object may be read at the same instant the object is observed. The bearings are read on a floating card, graduated and numbered from zero to 360° , so that no error can be made in substituting one quadrant for another. The instrument may be held freely in the hand while an observation is being made, although better results will be obtained if it is given a firm rest.

The **passometer** records the number of steps in the course. This number must be multiplied by the average length of step in order to get the length of course. The **pedometer** is *supposed to be adjusted to length of pace of the user*, and consequently will give the length of the course. The **odometer** is attached to the wheel of a vehicle and gives distances very accurately. However, the use of the odometer is often questioned, since it is believed that with it a line is often traversed which does not *follow the best general route*.

The **pedograph** consists of a compass and a reel of expendable thread. The thread is tied to some object so that, as the observer walks along, the thread is drawn out. The thread turns a pulley which rotates a friction wheel. The friction wheel rotates and moves lengthwise a cylinder carrying sketch paper. The angle of the friction wheel controls the relative rotation and lengthwise movement. The angle of the wheel is set by a "lubber line" on the compass, so that a course is plotted on the cylinder in the direction relative to the position of the lubber line. If the observer follows courses at which he sets the lubber line, the traverse he covers will be plotted on the cylinder.

The **Locke level** is a portable instrument in which the bubble and the observed object may be seen at the same moment. It enables the operator to keep the instrument horizontal while holding it in the hand like an ordinary spyglass, to define rapidly all visible points of the same elevation as his own, and to estimate from these the relative height of other points. It may be used in a variety of ways for reconnaissance where no great precision is required and where a more elaborate level is not at hand.

BAROMETRIC LEVELING ¹

16. The altimeter. The modern aneroid barometer, usually called an *altimeter* when graduated in feet, is a light portable instrument which indicates barometric pressure. It will show changes in barometric pressure as small as that caused by the change of elevation of 1 ft. It is operated by a closed cell from which most of the air has been exhausted and which, therefore, expands and contracts with slight changes in air pressure. The very slight movements of the cell are indicated through a chain of mechanism by comparatively large movements of a pointer around a dial. The position of the pointer for a given air pressure is not always the same but changes very slightly with the temperature of the instrument, the effect of hysteresis, and certain unaccountable movements here called **swing**.

In good modern instruments the effect of temperature seldom extends over a range of more than 2 or 3 ft of altitude. If very precise readings are required, the temperature of the instrument should be taken while it is being read and the reading corrected according to the instrument temperature calibration. The effect of hysteresis is negligible except when changes of pressure occur at rates only attainable in an airplane. The swing movements are usually not greater than 2 or 3 ft. But there is no proper way to correct for them. If desired, their effect can be reduced by comparing different altimeters at 3- or 4-hour intervals and assuming that any swing differences are proportional to elapsed time.

¹ This section is chiefly based on research by Philip Kissam sponsored by Wallace and Tiernan Products, Inc., Belleville 9, N. J., and first published in "Photogrammetric Engineering," Jan., Feb., Mar. 1944.

In use the altimeters should be protected from vibration and temperature extremes. They should be kept level when read to avoid errors from friction and unbalanced parts.

17. The relation between barometric pressure and altitude. The difference between the unit atmospheric pressures at two elevations must be equal to the weight of a vertical column of air of unit cross section extending between them. Accordingly, since the reduction of pressure upwards along the column is equal to the weight of air left behind, the rate of reduction in pressure per unit increase in height, at any point in the column, is the weight of a unit volume of air at that point,

$$-\frac{dp}{dh} = w \quad \text{or} \quad dh = -\frac{1}{w} dp \quad (1)$$

where p = pressure

h = height

w = weight of air per unit volume

In surveying altimetry, the content of the air, the temperature, and the force of gravity are assumed to be constant throughout the column. Under these conditions the unit weight of the air is a function of the pressure, as air obeys Boyle's law with negligible error.

By Boyle's law

$$pv = p_0v_0 \quad \text{and} \quad \frac{p}{w} = \frac{p_0}{w_0} \quad \text{or} \quad \frac{1}{w} = \frac{p_0}{w_0} \times \frac{1}{p}$$

where p_0 , v_0 , and w_0 are known values, respectively, of pressure, volume, and the weight of a unit volume of air.

Substituting for $1/w$ in equation 1

$$dh = -\frac{p_0}{w_0} \frac{dp}{p}$$

Integrating from p_0 to p gives

$$h = -\frac{p_0}{w_0} (\log_e p - \log_e p_0)$$

or

$$h = \frac{p_0}{w_0} \log_e \frac{p_0}{p} \quad (2)$$

where h is the height from a point in the column where the unit weight of air is w_0 and the pressure is p_0 , up to a point in the column where the pressure is p .

To implement this equation the *Smithsonian Institution* publishes a table, *Table 51, Smithsonian Meteorological Tables* 1931, which give values for h in terms of feet based on the following:

$p_0 = 29.900$ in. of mercury (standard for sea level)

$w_0 =$ the best value obtainable for:

1. Dry air.
2. Pressure, 29.900 in. of mercury.
3. Temperature, 50° F.
4. Gravity at sea level at latitude 45°.

If all the constants involved including the modulus of common logarithms are combined, the working formula used to compute the table becomes

$$F = 62583.6 \log \frac{29.9}{B} \quad (3)$$

where F is in feet above the point where the pressure is 29.9 in. of mercury and B is the observed pressure in inches of mercury at the upper point. Values are given at intervals of 0.01 in. from 12 to 30.90 in.

18. The calibration of an altimeter. A surveying altimeter is calibrated by exposing it to measured barometric pressures, and marking the corresponding positions of the pointer with the computed values in feet, usually in accordance with the Smithsonian Table.

19. Field corrections. When the altimeter is used in the field, the atmosphere seldom has the value of w_0 that was used in computing the number of feet for calibration. When accuracy is desired, therefore, corrections must be made for the w_0 value encountered. The temperature and moisture content can be measured by wet- and dry-bulb thermometers and the value of gravity estimated from the altitude and the latitude. Chart I,¹ which is entered with these data, gives the corresponding corrections to be applied to the readings when the altimeter is calibrated according to the Smithsonian Table.

20. Changes in barometric pressure. Barometric pressures change rapidly and irregularly at any one place, as cyclones and anticyclones pass by. The effect of these changes on altitude measurements can be eliminated by stationing an

¹ From "Photogrammetric Engineering," Vol. X, No. 1, in article by Philip Kissam entitled "Precision Altimetry."

AIR TEMPERATURE PLUS HUMIDITY CORRECTION FACTOR

This chart should be used only with altimeters which are set and calibrated to read in feet according to the Smithsonian Meteorological Table 51 of 1931.

NEARLY VERTICAL CURVES ARE LINES OF EQUAL DRY BULB TEMPERATURE
HORIZONTAL LINES ARE LINES OF EQUAL WET BULB TEMPERATURE
VERTICAL LINES ARE LINES OF EQUAL CORRECTION FACTORS
----- LINE OF AVERAGE HUMIDITY
(USE WHEN NO WET BULB READINGS EXIST)

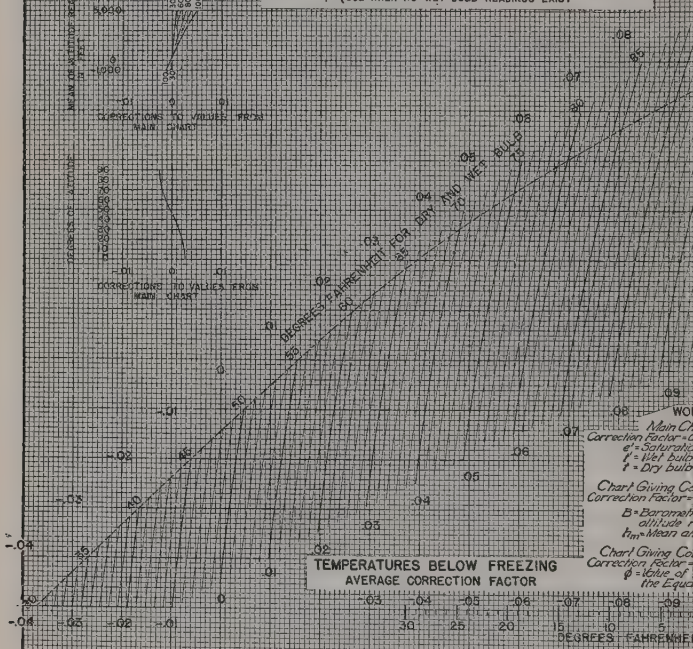
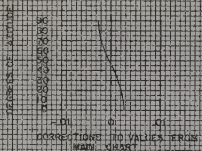
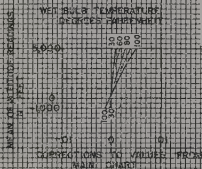
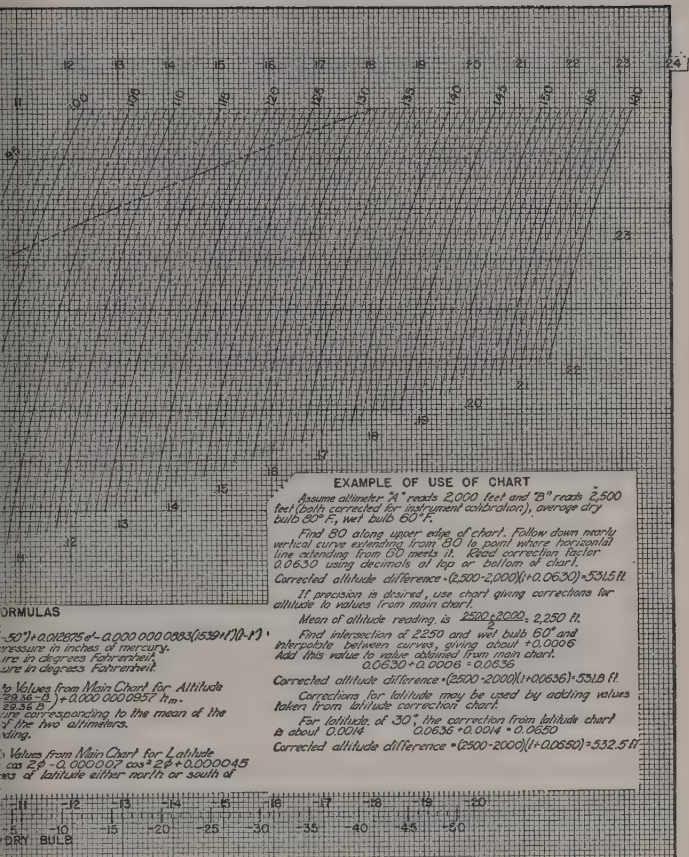


CHART I. Correct



tors for altimetry.



altimeter at a known elevation and recording its indications at frequent intervals while a second altimeter is being used to find elevations. The difference between simultaneous readings of the two instruments, when corrected according to the chart, is applied to the known elevation to find the required elevation.

21. Wind. A barometric gradient may exist between two places at any time. It is always accompanied by a wind blowing somewhat at right angles to the gradient and with a force which is approximately a function of the steepness of the gradient. Also, when the wind is blowing, large and small topographical features create widespread and local eddy currents which form pockets of barometric irregularity. Accordingly, it is impossible to use barometric leveling successfully in a strong wind. It has been found, however, that winds of 10 mph or less cause negligible errors in even the most precise work.

22. The two-base method.¹ The most accurate and one of the simplest methods of barometric leveling is known as the **two-base method**. An altimeter is stationed at each of two known elevations, preferably one above and one below the range of points where elevations are to be obtained. Two elevations can then be determined for every point, by the altitude differences from the upper and the lower bases, respectively. Except for minor irregularities of the instruments, any difference in the two elevations, thus determined, is due to the temperature and composition of the air and the force of gravity having values that combine to give a w_0 that is not the same as that used in the calibration of the instruments.

From equation 2 it is evident that h bears a straight line relationship with w_0 , and, hence, if the value of w_0 is assumed to be momentarily the same throughout the area surveyed, the difference between the elevations can be adjusted in proportion to the altitude differences.

This method eliminates the necessity for measuring the temperature or the moisture content of the air, or for using a correction for gravity. It, in fact, measures the effect of w_0

¹ See also Technical Publication 251, Wallace and Tiernan Products, Inc., Belleville 9, N. J. The use of two bases was first suggested by G. K. Gilbert in the annual Report of the Director, "U. S. Geological Survey," 1880-81.

directly at the moment of observation, eliminating any uncertainty of estimation. By using *two determinations* of each elevation, the advantage of an average is also obtained.

FIELD ALTIMETRY

23. Field procedure for barometric leveling. The two-base method is here given in detail. Other methods are outlined. It is thought that with one detailed procedure before him, the engineer can establish his own procedure for other methods in accordance with the problem in hand.

24. The two-base method. Using good altimeters, this method gives elevations within 1 or 2 ft. It is suitable for the control of an aerial survey for mapping 10-ft contours or for 5-ft contours when combined with spirit leveling as described under aerial mapping. Other uses requiring less accuracy require less rigid specifications.

The chief restrictions are the following: The wind velocity shall not be greater than 10 mph, the area covered shall not be greater than 20 miles square, and the elevation range shall not be greater than 200 ft. (Wider limits can, of course, be used, but with a corresponding reduction in accuracy.)

An altimeter is located at each of two base stations at known elevations, preferably one below and one above the range of elevations to be determined. They should be located near the center of the area to be covered, in the shade, and read every 2 minutes. Frequent instrument temperatures must sometimes be determined.

While the base instruments are in operation, any desired number of field observers can be at work. Each field observer should have two altimeters. Both instruments should be read at every field station. Five readings of each instrument should be made at intervals of 2 minutes. The instrument temperature should be determined.

For each field station the five readings of each of the instruments are averaged. The five readings made at the corresponding times at the base stations are then selected and averaged. The instrument corrections are applied to the averages. Two altitude differences will result, one from the upper base and one from the lower base. The application of these differences to the elevations of the bases results in two

elevations for the field station. These are adjusted in proportion to the altitude differences.

This procedure eliminates the necessity for any correction caused by variations in unit weight of air, that is, corrections for temperature, humidity, altitude, and latitude; it eliminates the uncertainty of these corrections and further increases the accuracy by providing four readings for each observation.

25. Instrument corrections. Usually instrument corrections can be neglected as they are so small. For high accuracy they must be included. They are:

1. *Correction for temperature.* Instrument readings are corrected for instrument temperature by means of the calibration chart furnished with the instrument.

2. *Correction for swing.* The index correction of each instrument with respect to any one instrument (usually a base instrument) should be determined just before and just after the field observations. The index correction applied to any reading is interpolated between the two index corrections observed, in relation to elapsed time.

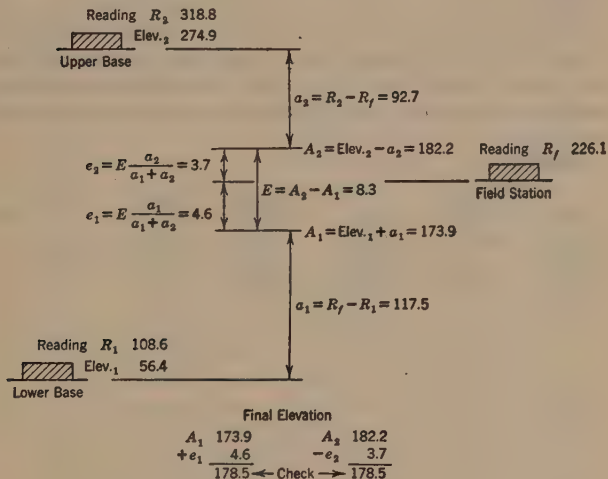


FIG. 1.

26. Illustrative example. The example given is illustrated in Fig. 1. The example consists of the determination

of the altitude of a single **field station**. The lower base has an elevation of 56.4 ft. The upper base has an elevation of 274.9 ft. The computation is illustrated. The readings shown are averages with the instrument corrections applied.

27. The one-base method. The same field procedure is followed as for the two-base method, except that only one base is used and dry- and wet-bulb temperatures are taken at frequent intervals at the base station and during the readings at the field station. Only one field instrument is used by each observer.

After the instrument corrections are applied, the method results in an altitude difference. This must be corrected for unit weight of air by use of the chart. The corrected difference applied to the base elevation gives the desired elevation.

28. Single-altimeter method. The single-altimeter method can never be very accurate, and, therefore, all instrument corrections are negligible. Air temperatures should be taken and the chart used by correcting readings for air temperature at average humidity only. No other corrections need be applied.

The altimeter should be read at known elevations as often as possible. An index correction should then be computed for each field station based on the index corrections observed at each known elevation and interpolated according to elapsed time.

Example.

Station	Known Elevation	Time	Corrected Readings	Index Correction	Final Elevation
B.M. 1	560.7	8:00 A	710.7	-150.0	
Field A		9:00 A	420.0	-160.0	260.0
Field B		10:00 A	970.0	-170.0	800.0
B.M. 2	1000.2	12:00 N	1190.2	-190.0	

CHAPTER III

THE PRELIMINARY SURVEY AND PROJECTING LOCATION

29. A preliminary survey consists in an instrumental examination of the country along the proposed route, for the purpose of obtaining such details of distances, elevations, topography, etc., as may be necessary to prepare a map and profile of the route, make an approximate estimate of the cost of constructing the road, and furnish the data from which to locate the line definitely, if the route should be adopted. The survey is more or less elaborate, according to circumstances. If the country is new, or the reconnaissance has been incomplete, or if several routes seem to offer almost equal inducements, the survey will have some of the characteristics of a reconnaissance and will be made more hastily than if only one route is to be examined, and that route, perhaps, presenting serious engineering difficulties. The survey is made as expeditiously as possible, consistent with general accuracy, but should not usually be delayed for the sake of precision in matters of minor detail.

The majority of preliminary surveys in the United States are made by the **two-instrument method**, although there is a tendency towards use of the *stadia*. The term "two instrument" method arises from the fact that the *two principal* surveying instruments used are the transit and the level.

30. Preliminary survey procedure. The preliminary survey is controlled by a single continuous open traverse established by the **transit party** and a profile run over it by the **level party**. The **topographer** or a **topographic party** maps the topography and culture by measurements from this control. This procedure is somewhat altered when the preliminary survey is to be mapped from the air. See section on aerial mapping.

31. The traverse. The traverse is placed as nearly as possible along the route of the final location line by running from one governing point to the next and keeping the line approximately on the established grade between them. It is permanently marked in the field by a hub and guard stake at each of the angle points, which are the instrument positions, and by a long stake at each of the **stations**. The stations are set at intervals of 100 ft, measured continuously from the beginning, along the entire traverse. The angle points do not interrupt the stationing. The distance from the previous station to an angle point is recorded, and the next station is set by measuring forward the remainder of the 100 ft. Stations are numbered consecutively from the beginning point which is called station 0. The positions of the intermediate points along the traverse, including the angle points, are given by their "plus" which is the distance from the last previous station. For example, an angle point 82.6 ft beyond station 11 would be called 11+82.6, and it would be 1182.6 ft. from station 0. Station 12 would be set 17.4 ft beyond the angle point. The total distances between angle points are the lengths of the **courses**. They must be found by subtracting the plus of the angle point at the beginning of the course from the plus of the angle point at the end of the course. The + mark placed between the station number and the plus has come to indicate that all positions on the traverse are measured from a common point of beginning. Stations, therefore, are usually marked thus, 11+00 or 11+0 (for station 11). The form of traverse notes is shown in Fig. 2.

32. Accuracy. The accuracy required is very low—only that necessary for mapping. One part in 300 is high enough. One part in 2000 is usually attained. Blunders, of course, will cause great difficulty and serious loss of time.

33. Angle measurement. Traverse angles are usually measured with a transit. They are then recorded by deflection angles, by clockwise angles turned from the backward direction to the forward direction, or by compass bearings alone. Angles should be doubled to avoid blunders. The measured compass bearing of the first course should be assumed to be correct, and thereafter the **computed** bearings should be calculated from the angles measured. The computed bearings should be checked against the actual compass bearings to

Sta.	I D	I DR	Used	Mg. Br.	Cal. Br. Dist.	Ch. H.C. H.C. R.C.	Rule Hale Doe Roe	Date clear
32 31+12.8 31	189° 10'	18° 20'	189° 10'					
30 29				N 86° 10' W	N 86° 18' W 345.3			
28 27+67.5 27	188° 09'	16° 20'	188° 10'					
26				S 85° 20' W	S 85° 32' W 309.4			
25 24+58.1 24	209° 01'	58° 03'	209° 01'					
23 22+21.3 22	197° 28'	34° 56'	197° 28'	S 56° 30' W	S 56° 31' W 236.8			



FIG. 2.

avoid blunders. When traverses are run near railroad tracks or other sources of serious local attraction, the bearings should be checked by sun observations. The solar attachment is excellent for simplifying these observations. When a traverse runs east or west, the magnetic or solar bearings must be corrected for the **convergence of meridians** which is equal to the difference in longitude multiplied by the sine of the latitude.

There are many advantages in using a compass instead of a transit. It is light and easy to use, errors cannot accumulate, and with it the line can be carried past obstacles with ease. Both backsights and foresights should be recorded.

34. Distance measurement. Distances should be measured with a steel tape graduated throughout its length. The 100-ft end should be kept forward. Stations should be aligned by the rear tapeman by eye. Pluses to angle points are customarily measured to the nearest foot.

To avoid blunders in measurement at angle points, the following procedure is recommended. As soon as the plus is determined, the tape should be laid down on the ground. The rear tapeman should then go forward and hold the tape graduation at the hub that corresponds to the plus of the hub. The head tapeman can then set the next station at the 100-ft mark. Finally, the tape should be stretched between the two stations on either side of the hub while a third member of the party holds the tape on the hub and notes the plus. This check is, of course, approximate.

The tapeman must take the greatest care to avoid blunders in marking the stations. Most errors in measurement occur because two stations have been given the same number or a station has been omitted. To stop the head tapeman, instead of calling "chain," the rear tapeman should call the number of the station he is approaching. When asked for a station number, he should always call the number of the station *where he is standing*, adding the word "here." He should never call the number that the head tapeman should put on the stake.

35. The profile. A profile of the transit line is run by the level party following as closely as possible behind the transit party. Elevations are determined of the ground at each station and at all breaks in slope between stations. A benchmark

should be set at about every 10 or 15 stations and at every stream crossing where it can be used for setting masonry. If possible, benchmarks should be set clear of construction so that they can be used throughout the location survey and the building of the line. The plus and offset of each benchmark should be included in its description. The level party should carefully check the station enumeration, and for this reason, as well as to avoid errors in the profile notes, the rodman must call the number of each station when he places his rod beside it.

Whenever the level party overtakes the transit party they should turn back to check their benches by benchmark leveling, arranging the work so that each bench is established by at least two lines of levels.

36. Topography. Topography is taken by every available method. Aerial photography, the plane table, stadia, the clinometer, sketching by eye, or any combination of these methods is used. A special method of mapping contours was developed many years ago and still appears to be the cheapest ground method where considerable accuracy is required. It is described in the following section.

37. Procedure for finding contours. Using a hand level and a metallic tape, the position of each contour is found on lines at estimated right angles to the traverse. The lines are usually placed at the stations and are spaced according to the accuracy desired.

The method is illustrated in Fig. 3. A forked stick is cut so that the hand level is exactly 5 ft from the ground when supported in the fork. If, for example, the ground at station 25 has the elevation 32.0, the target is set at 8.0 ft and the instrumentman moves uphill until his instrument is level with it. The foot of the stick will then rest on the 35-ft contour. The offset is measured. The rod is then set at 10.0 ft and moved up to the position occupied by the stick. When the hand level is again sighted on the target, the stick will be at the 40-ft contour. The increment to the offset is measured and added. This is continued as far as desired.

Working downhill (as shown in Fig. 3 at station 26), the instrument is kept uphill as before. The elevation of station 26 is 31.2. Accordingly, the target is set at 6.2, and the rodman moves as directed until the target is level with the instrument.

By always keeping the instrument uphill from the rod, the line of sight is kept above most of the underbrush.

The process is carried out on both sides of the line, usually at every station, but sometimes at greater intervals. The contours are immediately plotted in the notes and sketched between stations by eye. All other topographical features and culture are mapped at the same time. One form of notes is shown in Fig. 4.

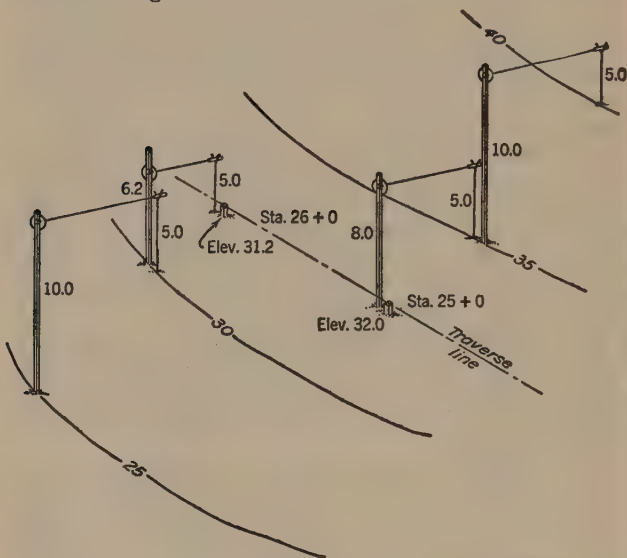


FIG. 3.

38. Topographical features included. The map must show everything that might affect the choice of location. These include: contours, streams and other bodies of water, with high-water marks and runoff data, roads, buildings, approximate property lines with owners' names and approximate land values, soil and rock conditions, limits of woods where clearing and grubbing are required.

39. In the two-instrument method the Corps of Engineers is organized as follows: transit party; level party; and topographer, with one or two assistants. The duties of the various positions are outlined here.

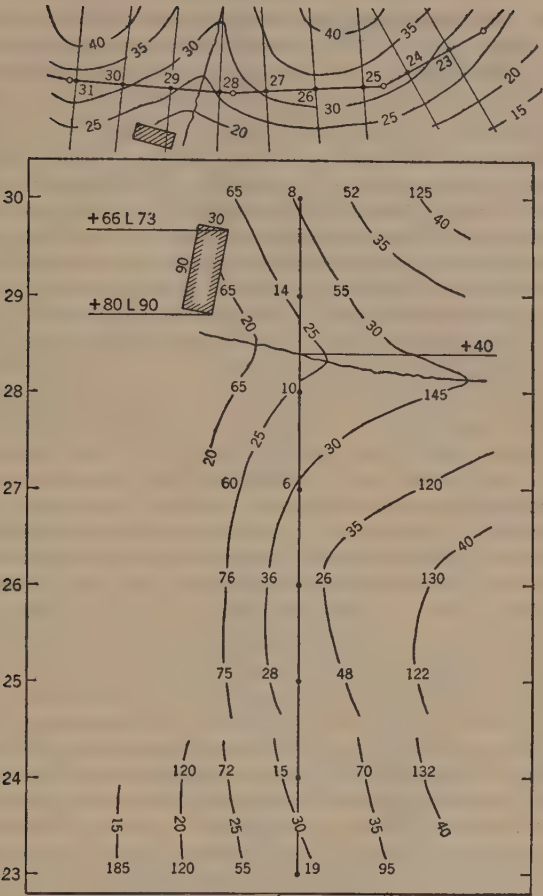


FIG. 4.

THE TRANSIT PARTY

40. The locating engineer takes charge of the corps and directs the survey. He ascertains or estimates the value of the lands passed over, the owners' names, and the boundary lines crossed by the line of survey. He examines all streams and estimates the size and character of the culverts and bridges which they will require; he notices existing bridges and inquires concerning the liability of their being carried away by freshet; he selects suitable sites for bridges, examines the character of the foundations and the direction of the current, and considers any probable change in the direction of the current during freshets; he inspects the various soils, rocks, and kinds of timber as they are encountered and makes notes of these and similar items in his field book. In addition, he not infrequently assumes the duties of topographer. He should run his line as nearly as possible over the ground likely to be chosen for location, so that the information obtained may be pertinent, and so that the length of the line, the shape of the profile, and the estimate based on the survey may approximate those of the proposed location. Accordingly, he notes the levels taken, and, when they show that the line as run fails to be consistent with allowable grades, he orders the corps back to some proper point to begin a new line, or makes an offset at once to the better position, or continues the same line with some deflection, simply noting the position and probable elevation of better ground, according to his best judgment. He should at all times maintain a friendly attitude toward proprietors, and by his polite bearing endeavor to secure their cordial support of the new enterprise. If he is tolerably certain that the location will follow nearly the line of the preliminary survey, he should have with him some blank deeds of right of way, and have these signed by land-owners while they are favorably disposed. When this cannot be done, a blank form of agreement to allow the surveys and construction of the road to proceed until such time as the terms of right of way may be agreed on will be very useful. He also selects quarters for his men, and in case of camping out he directs the movements of the camp equipage.

41. The transitman measures the angles and takes the bearings of the courses run and makes a record of them, with their

lengths, and the plusses of the points, where they terminate. He sees that the axemen keep in line while clearing, and the chainmen while measuring; he takes the bearings of the principal roads and streams and of property lines encountered. In an open country he may save time by selecting some prominent distant object toward which the chainmen measure without his assistance, while he goes forward and prepares to take the direction of the course beyond. In traversing a forest with not too dense undergrowth, when the line is being run to suit the ground according to a given grade, it is a good plan for the transitman to go ahead of the chainmen as far as he can be seen, select his ground, take his direction by backsight on the last station, and then have the chainmen measure toward him. In this case both he and the head chainman should be provided with a good-sized red and white flag, mounted on a straight pole, to be waved at first to call attention, and afterward held vertically for alignment. Otherwise a flagman must be added to the party, who will select the ground ahead under the instructions of the locating engineer, and toward whom the survey will proceed in the usual manner.

Transit notes may extend across both pages of the field notebook, the right-hand page being reserved for sketches. The notes should extend from bottom of page upward, the red line on the right-hand page thus corresponding to the center line on the ground. Deflection angles should be carefully doubled and magnetic bearings read as a check on the angular work.

A brief outline of the **transit adjustments** is given in Chapter XX, and such adjustments should be checked as opportunity offers.

42. The head chainman drags the tape and carries a flag which is put into line at the end of each chain length by the transitman or the rear chainman. It is the head chainman's duty to know that his flag is in line and that his tape is straight and horizontal before any measurement is made, and to show the stakeman where each stake is to be driven. A stake is usually driven at the end of each measured chain length, called a station, though in an open and level country the stakes at the odd stations may be omitted, in which case marking pins are used to indicate the odd stations temporarily. If there is much clearing to be done the head chainman plants

his flag in line and, ranging past it, indicates to the axemen what is to be cut, going a little in advance through the bushes so that they may work toward him. *The head chainman should be a quick, active, and strong man, with a good eye and a taste for his work, as very much of the real progress of the survey depends on him.*

43. The rear chainman keeps the tally by the pins when they are used and watches the numbers on the stakes to see that they are correct.

44. The axemen should be accustomed to chopping and clearing, and, therefore, should be selected in the country rather than the city. They will cut out as much of the underbrush and overhanging branches as may interfere with the sight of the transitman or leveler; but they must be careful not to cut unnecessarily wide, and no tree of considerable size should be felled, except in unusual circumstances. When running by compass, if the transitman goes ahead of the chain, he can always select a position so that no large tree will interfere; or, if the line must be produced and strikes a tree, the transit may be brought up and set close to the tree on the forward side as nearly in line as can be estimated, the slight error in offset being neglected, since the line will be produced parallel to itself by the needle.

45. The stakeman prepares and marks the stakes and drives them at the points indicated by the head chainman. When no clearing is needed, the axemen keep him supplied with stakes, since the rapid progress of the chain will give him only time to drive them. The stakes should be 2 ft long and pointed evenly so as to drive straight. They are blazed or faced on two opposite sides, one of which is marked in red chalk with the number of the station. The stake must be driven vertically and with the marked face to the rear so that it may be read by the rodman as he follows the line.

THE LEVEL PARTY

46. The leveler takes charge of the level party and keeps notes of his work. He should direct a bench to be made at least once every half-mile and in a very rough country every quarter of a mile. He should continually bear in mind that the levels are usually the most essential part of the survey.

The leveler should make every endeavor to follow closely after the surveying party, so that the locating engineer and topographer may have the advantage of his notes.

47. The rodman's first duty is to hold the rod for a reading on the ground at every stake, the number of which is called out to the leveler as soon as the rodman reaches it. The rod should also be held at every prominent change of slope on the line, as the crest and foot of every bank, the rodman calling out its distance from the last stake as *plus* so many feet, but all gentle undulations and minor irregularities should be neglected. The rod will always be read at the surface of a stream or pond and also at its deepest part on the line when possible; otherwise, the depth of the water may be found by sounding and so recorded. If the line runs along a stream, the surface will be taken occasionally, opposite certain stations, and, if it runs along a canal, the elevation of surface above and below each lock must be noted. The rodman makes inquiry for *high-water marks* or seeks traces of them himself in an uninhabited district, and holds the rod on them so that their elevation may be determined. The rodman carries a small axe or hatchet with which to make benches and to trim out any stray branch that may intercept the leveler's view.

TOPOGRAPHY

48. The topographer makes accurate sketches in a book prepared for the purpose of all features of the country immediately on the line and extends the sketches as far each side of the line as he can. He must never sketch in advance of the chain nor in advance of his own position. His work should be done to scale as nearly as possible, the same scale being used for distances on the line and at right angles to it. The scale adopted should never be less than that of the map to be made from the sketches. The ruled lines of a field book are usually $\frac{1}{4}$ in. apart, so that the scale of one line to a station equals about 400 ft to an inch. This is the smallest scale ever used. The scale of two lines to a station is most convenient for general use. Four lines to a station are needed in special cases to show details, as in passing through villages. The scale may be changed from time to time as found necessary, but no two scales should ever be used on the same page. The numbering

of the stations up the page indicates the scale of the sketch.

49. When the contours of the surface are required, the topographer may join the level party in order that his estimates of heights and slopes may be corrected by the instrument. He should never draw a mass of contours indiscriminately but should sketch them as they exist at a uniform vertical interval. This interval may be assumed at 5 ft in a gently rolling country and at 20 ft in a mountainous one, but an interval of 10 ft will be found most convenient generally. If the topographer accompanies the level, he can assume the contours at the even tens of feet in elevation and mark them so, noting where a contour crosses the surveyed line and sketching its direction and shape both ways from that point. He will estimate the rate of slope of the ground at right angles to the line as so many feet per hundred and record it from time to time, noting ascent from the line on either side by *A* and descent by *D*. If the slope changes within the limit of the page, the line of change may be sketched and the next slope recorded. When little banks or terraces occur, or bluffs and rocks, which cannot be sufficiently indicated by contours, they should be shown by hatchings, and the height noted. Special care should be taken to sketch roads and houses in their correct positions and dimensions, the latter to be measured, paced, or estimated. The dimensions should also be recorded in numbers. The outline of forests may be shown by a scalloped line and the kind of timber, and whether dense or scattered, written within the inclosed space. Correct outlines are essential, but no time should be given to shading up a sketch with conventional signs. A single sign, or the name of the object designated, is sufficient. Landowners' and residents' names should be recorded whenever they can be obtained, as well as the names of roads, streams, and public buildings.

50. Where detailed information is desired on a narrow stretch of country near the preliminary line, one or more rodmen may assist the topographer in securing it. The contours and all important features such as highways, fences, buildings, and bodies of water, should be located. A contour may be located either by hand level, level rod, and tape, or by horizontal and vertical rods. The first method is probably

in more general use, but the second has a decided advantage in the fact that the work may be done independently of the level work.

The work of obtaining contours by use of hand level and rod or by slope board is often called "cross-sectioning." The Locke hand level and level rod are generally used on preliminary surveys, whereas slope boards or cross-section rods have many advantages for steep slopes and for double-tracking work.

STADIA METHOD

51. Surveys made by transit and stadia have many advantages over the so-called two-instrument method. Among these may be mentioned: the comparatively large area which may be covered with less expense; a smaller amount of clearing of underbrush and foilage; and the quietness with which the survey may be conducted. Among the disadvantages of the method are: a large amount of reductions and plotting, and the lack of as definite a reference line on the ground for use during the location survey.

There seems to be a tendency toward the use of the stadia method for preliminary surveys.

TOPOGRAPHICAL SKETCHING

52. Topographical sketches taken on preliminary surveys are usually of great value in projecting a line for location; they should be made therefore as accurate and complete as possible. In too many instances sketches are presented having a picturesque appearance, but conveying little information, if not tending to mislead the mapmaker. The aim of the topographer should be to record the topographical features either side of the line with as much precision as those directly on the line, without taking actual measurements, except in rare instances. The eye and the judgment must be usually depended on for distances and dimensions. The sketch of a tract extending 400 ft each side of the line ought to be accurate enough to warrant its being copied literally on the map. If a much wider range is required, it may be advisable to use the plane table; but an approximation of plane-table methods may be employed in ordinary sketching.

53. As **artificial features** are the most readily defined and located, these should first receive attention when a sketch is made. When recorded, they form a skeleton on which the natural features can be drawn with more precision than if the order were reversed. The point where each fence crosses the line and the angle between the two may be sketched exactly. The distance along the fence to any object may be estimated, and checked (in case of an oblique angle) by observing where a line from the object perpendicular to the center line would intersect the latter. The book may be rested on any support, the center line of the page coinciding with the line of survey, and the direction of objects defined by a small ruler laid on the page. This operation being repeated from another point gives intersections which locate the several objects on the sketch. If the bearings are taken, they may be plotted on the page as well as recorded, giving the same results. The eye may be trained to estimate distances correctly by observing the appearance of objects along the measured line, the distances to which are therefore known.

54. After the artificial objects the more distinct **natural features** are to be sketched, as streams, shores, margins of swamps, forests, ravines, ridges, and bluffs, and care should be taken that all these outlines intersect the features of the sketch already delineated at the proper points. The correct representation of **contours** is the most difficult part of sketching, since these lines are quite imaginary; yet, for railroad maps they are usually as important as any others. It is desirable to know not only the locality of a hill or slope, but also its shape, steepness, and height. This information is best given by contour lines. A practiced eye is able to follow on the ground the course of a contour with all its windings; but in sketching them due allowance must be made for the foreshortening effect of distance. All contours on the same sketch should have the same vertical interval, so that by counting them the height of the hill may be known. The spaces on the sketch between contours vary as the cotangent of the slope angle, so that the width of the spaces indicates the degree of steepness. The contours nearest the topographer should generally be sketched first, although, if there be a shore, that is apt to be the best guide to the shape of the slopes. If the height of the hill is known and the upper contour located, the other contours can be spaced between with less

difficulty, the proper number being ascertained by dividing the height by the assumed vertical interval. A special line of levels or a stadia shot up an inclined ravine or sloping ridge to fix the contour points is often of the greatest service in obtaining correct results. Other random lines are sometimes run to locate the contours more definitely. These should be made to cross several contours rather than to trace a single one. Old preliminary lines which have proved useless in themselves often furnish by their profiles valuable information in respect to contours.

The use of hatchings should be avoided in the sketchbook, except to represent precipitous banks, or slight terraces, which would not be sufficiently defined by the contour system. Hatchings freely used consume too much time, fail to give an accurate idea of either slope or height, and obscure the page for the representation of other objects.

55. The center line on the page is straight, and for sketching purposes the surveyed line on the ground is assumed to be so also. Slight deflections in the course of a preliminary line may be ignored in the sketch; but, if a large angle occurs, it is better to terminate the sketch with the course, and begin again, leaving a few blank lines between the two sketches. On a located line with curves, the sketch is continuous. The curved line in the field is represented by the straight line on the page, and the radial lines through the stations are represented by the parallel lines ruled across the page. All objects are sketched at the proper offset distance by scale from the center line; but longitudinally the sketch is necessarily diminished outside of the curve and magnified inside of the curve. Consequently, topographical lines which are straight in fact appear curved in the sketch, concave to the center line if inside the curve, and convex if outside of it. Such features are correctly sketched by means of offsets estimated or measured from each station of the curve on the radial lines. This kind of distortion creates no confusion if properly done, for in making the map, after drawing the curve and the radial lines, the same offsets will give the correct positions of the objects delineated. This method is preferable to drawing a curved line on the page to represent the center line, as it is difficult to draw it correctly; it will cross the ruled lines obliquely, rendering them of no service for offsets or scales, and, moreover, is likely to run off the page altogether.

59. Plotting stands and sometimes **control stands** are placed on the map. Plotting stands consist essentially of small tables with white circular tops about 5 in. in diameter that are adjustable in height. In the center of each plotting stand, flush with the top surface, is a tiny bright white light, and directly underneath is a pencil that normally rests on the paper but can be raised clear of it. On a control stand, a dot and a pointer replace the light and pencil.

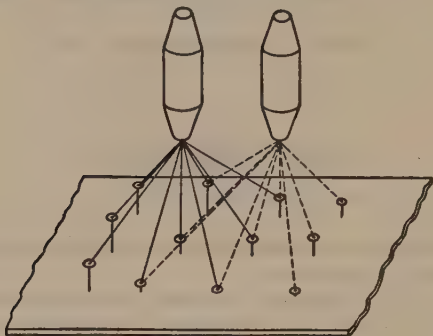


FIG. 6.

By placing these stands over the plotted positions of the photo-control points and adjusting the heights of their top surfaces to the map-scale elevations of the photo-control points, a space model to the map scale of the photo-control points is established. Either separately or in pairs each projector is adjusted so that the images of the photo-control points fall on their respective marks. This re-creates, to map scale, the geometric conditions that existed when the photograph was taken. See Fig. 6.

When two overlapping photographs are thus projected, a radial line from each photograph is projected for every object pictured in the area of overlap. These pairs of lines intersect at the map-scale positions and elevations of the objects. The intersections can be found by stereo viewing. A red filter is placed on one projector and a green filter on the other. Wearing a red glass over one eye and a green glass over the other eye, the operator sees a stereo model on any surface interposed in

the overlap. When a plotting stand is placed in this area, the stereo model can be seen on its white surface. Since the white light can be seen with both eyes, it has apparent height with respect to the model. When the light is placed at the intersection of the two rays to an object, it appears to be on the

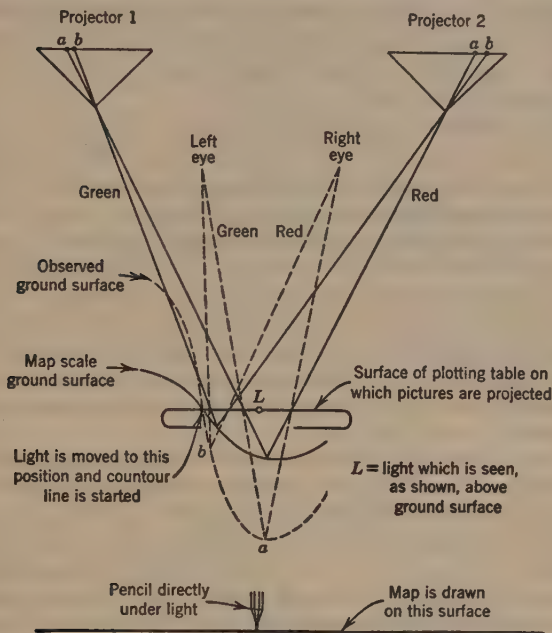


FIG. 7.

object both in position and elevation. See Fig. 7. The stand surface is first set at the elevation of a desired contour line to the map scale and then moved until the light apparently touches the ground. The pencil is lowered to the map, and the light is moved along the apparent ground surface, causing the pencil to trace the contour line. All contour lines desired can be plotted in this way. Planimetry is plotted by following the object to be plotted and at the same time raising or lowering the mark so that it apparently stays on the ground surface.

Theoretically, once one photograph is in position, all overlapping photographs can be correctly positioned by using pass points. Actually, the accidental errors would accumulate too rapidly for accurate mapping if this system were used alone. Accordingly, the accuracy of the map depends on the density of ground control. As elevations must be determined much more accurately than horizontal positions, more elevations than horizontal positions of photo-control points must be determined in the field.

60. Accuracy. In addition to the density of ground control, accuracy depends on the flying altitude, the excellence of the photographic equipment, and the precision of the photogrammetric process used to make the map. Low altitude increases the accuracy if the photographic equipment is fast enough to avoid blurring the images. Glass plates retain the true shape of the photograph much better than film. Different plotting processes vary widely in results. Mapping procedures, accordingly, vary widely in accuracy. Up to a certain limit, however, any desired accuracy can be obtained by increasing the ground control and by decreasing the flying altitude.

The accuracy is usually specified as follows: wherever a test profile may be run, the map shall be correct within one-half a contour interval for 90% of the profile. Aerial mapping processes are rated according to a **C Factor**¹ which is the flying altitude necessary for the accuracy previously specified, divided by the contour interval desired. Good processes have C Factors ranging from 600 to 1500. Accordingly, for a desired contour interval of 5 ft, the altitudes required would lie between 3000 and 7500 ft.

61. The procedure for using air mapping in location. Usually a single flight strip is flown over each proposed route. Sometimes certain areas are covered by several strips. When a system of survey control points exists where map is to be located, the positions and elevations of the photo-control points can be determined from the markers of this system. The paper location line can be projected on the resulting map, and the quantities of cut and fill can be estimated directly.

¹ Originally suggested by Russell K. Bean, U. S. Geological Survey.

from it. The map, of course, will show no traverse from which to establish the location line in the field. This is accomplished by measurements from the control system or from objects shown on the map.

When no survey control exists, a traverse and a line of benches must be established along the route. The flight strip is then flown so that it approximately centers on this line. Photo-control points near the traverse are tied in for both position and elevation, distant points for elevation only. Stadia can be used for all these ties, but barometric leveling is excellent for determining the elevations of the distant points.

62. Other advantages of aerial mapping.¹ In addition to the reduction in cost and the greater detail supplied, aerial mapping has several unique advantages not available in ground surveys.

1. With very little additional cost, the full width of the flight strip can be mapped instead of a narrow strip along the probable line. This results in a map usually at least a mile wide. The extra width obtained is of great importance in built-up areas where property values are high or where intersecting roads or special drainage conditions must be considered.

2. An air map can be made with a minimum of ground operations. This avoids trespass and eliminates rumors, land speculation, and objections to possible locations which are surveyed but not used.

3. Approximate property lines can usually be mapped. They are often visible on the photographs when difficult to find on the ground. They afford a basis for preliminary agreements with landowners.

4. The photographs themselves have many uses. They provide an inventory of surface features showing blighted areas, traffic density, sources of gravel and construction material, the types of soil available, and the location of existing trees for landscaping. Made into mosaics they are useful for reconnaissance. They provide evidence of the limits of con-

¹ The statements in this section are quoted from a symposium on "Aerial Photography in Highway Location" held under the auspices of the American Society of Civil Engineers, Jan. 17, 1947. Participating were: E. T. Gawkins, Spencer Miller, Jr., W. J. Cox, and E. C. Houdlette.

Theoretically, once one photograph is in position, all overlapping photographs can be correctly positioned by using pass points. Actually, the accidental errors would accumulate too rapidly for accurate mapping if this system were used alone. Accordingly, the accuracy of the map depends on the density of ground control. As elevations must be determined much more accurately than horizontal positions, more elevations than horizontal positions of photo-control points must be determined in the field.

60. Accuracy. In addition to the density of ground control, accuracy depends on the flying altitude, the excellence of the photographic equipment, and the precision of the photogrammetric process used to make the map. Low altitude increases the accuracy if the photographic equipment is fast enough to avoid blurring the images. Glass plates retain the true shape of the photograph much better than film. Different plotting processes vary widely in results. Mapping procedures, accordingly, vary widely in accuracy. Up to a certain limit, however, any desired accuracy can be obtained by increasing the ground control and by decreasing the flying altitude.

The accuracy is usually specified as follows: wherever a test profile may be run, the map shall be correct within one-half a contour interval for 90% of the profile. Aerial mapping processes are rated according to a **C Factor**¹ which is the flying altitude necessary for the accuracy previously specified, divided by the contour interval desired. Good processes have C Factors ranging from 600 to 1500. Accordingly, for a desired contour interval of 5 ft, the altitudes required would lie between 3000 and 7500 ft.

61. The procedure for using air mapping in location. Usually a single flight strip is flown over each proposed route. Sometimes certain areas are covered by several strips. When a system of survey control points exists where map is to be located, the positions and elevations of the photo-control points can be determined from the markers of this system. The paper location line can be projected on the resulting map, and the quantities of cut and fill can be estimated directly

¹ Originally suggested by Russell K. Bean, U. S. Geological Survey.

from it. The map, of course, will show no traverse from which to establish the location line in the field. This is accomplished by measurements from the control system or from objects shown on the map.

When no survey control exists, a traverse and a line of benches must be established along the route. The flight strip is then flown so that it approximately centers on this line. Photo-control points near the traverse are tied in for both position and elevation, distant points for elevation only. Stadia can be used for all these ties, but barometric leveling is excellent for determining the elevations of the distant points.

62. Other advantages of aerial mapping.¹ In addition to the reduction in cost and the greater detail supplied, aerial mapping has several unique advantages not available in ground surveys.

1. With very little additional cost, the full width of the flight strip can be mapped instead of a narrow strip along the probable line. This results in a map usually at least a mile wide. The extra width obtained is of great importance in built-up areas where property values are high or where intersecting roads or special drainage conditions must be considered.

2. An air map can be made with a minimum of ground operations. This avoids trespass and eliminates rumors, land speculation, and objections to possible locations which are surveyed but not used.

3. Approximate property lines can usually be mapped. They are often visible on the photographs when difficult to find on the ground. They afford a basis for preliminary agreements with landowners.

4. The photographs themselves have many uses. They provide an inventory of surface features showing blighted areas, traffic density, sources of gravel and construction material, the types of soil available, and the location of existing trees for landscaping. Made into mosaics they are useful for reconnaissance. They provide evidence of the limits of con-

¹ The statements in this section are quoted from a symposium on "Aerial Photography in Highway Location" held under the auspices of the American Society of Civil Engineers, Jan. 17, 1947. Participating were: E. T. Gawkins, Spencer Miller, Jr., W. J. Cox, and E. C. Houdlette.

struction damage, and they are the best means of demonstrating to the public exactly what the proposed plans will effect.

5. The necessity of flying over the area provides an opportunity to obtain oblique views where complicated interchange facilities are planned. Oblique pictures often obviate the necessity of building models to study design.

CONSTRUCTING THE MAP

63. The preliminary survey is usually mapped at scales varying from 30 ft per inch to 200 ft per inch, depending on the importance of the detail to be shown. The scale chosen must allow convenient use of the available curve templates necessary for projecting the location.

It is best to plot the original map on a continuous roll of detail paper so that there will be a minimum of breaks. Where breaks must be made, it is well to repeat enough of the map to prevent the separation of a curve or a tangent into two parts when the location is projected.

The traverse may be plotted by coordinates or by computed bearings and scaled distances. Plotting directly from traverse angles should be avoided as it causes errors in direction, owing to the accumulation of plotting errors.

A blunder in computing or plotting the traverse introduces serious difficulties. It is usually not discovered until the location line is being staked out in the field. It may cause the estimated distance to be seriously in error, an angle to appear in a tangent, or either a curve or a tangent to depart radically from its desired position. After plotting, the lengths of the courses and the traverse angles should be measured by a scale and protractor and *checked against the original field notes*.

When the traverse has been thoroughly checked, the station positions are marked along it, and the topography is plotted. The map is immediately inked in color, fine ink lines being used.

The profile is usually plotted to a horizontal scale equal to or slightly smaller than the map scale. The vertical scale is usually ten times as large as the horizontal scale. The profile should be plotted on a continuous sheet of profile paper. Where breaks occur, enough of the profile is repeated to prevent separating uniform slopes.

PROJECTING LOCATION

64. Projecting a paper location consists of laying out on the map the first detailed position for the final line. The economic principles employed are the same as those on which the reconnaissance was based but are applied within narrower limits.

Where the line passes through built-up areas, the costs of right of way and construction are both high, and the solution must be based on careful and complete estimates of comparative costs. No rules can be laid down for this procedure other than the basic principles that heavy expenditures for surveys and tentative plans are usually justified, and a thorough investigation of every possibility is more than ever of paramount importance. Where the line passes through open country, the chief consideration is usually the cost of excavation and embankment. The problem resolves itself into a search for the line requiring a minimum of cut and fill. A step-by-step procedure has been developed for determining such a line, and it is described in the following paragraphs.

65. Scope. The line laid out is the center line of construction. It is, therefore, the center line of the cuts and fills, bridges, and so on. Usually this line is also the center line of the track (or tracks) or pavement, and it is often the center line of the right of way. The grades established are the elevations of the subgrade, which is the top surface of the finished excavation or embankment. Minor details of alignment or grade are usually neglected. Spiral curves (see Chapter IX) and the compensation of rate of grade for curvature (see § 375) are usually not introduced until after the preliminary-location center line has been staked out in the field.

66. Fixing grade lines. The procedure begins with the determination of grade lines. Essentially this consists of establishing the exact positions and elevations of the governing points. It is accomplished by a study of the preliminary traverse profile and map. One of the most important operations connected with the location, it is usually performed by the engineer in charge of the locating party, who is most conversant with the general character and detailed requirements of the line. Generally the maximum gradients will have been determined in advance from the preliminary data, according to the principles laid down in the preceding chapter,

but the position of each grade line relative to the profile of the surface must be left to the judgment and skill of the engineer. In general, the grade line is so placed as to *equalize the amounts of excavation and embankment*, within the limits of free haul (see § 301), but there are various *exceptions* to this rule. The excavation may be in excess: *first*, when it is necessary to pass under some other road or highway, the grade of which cannot be changed; *second*, when valuable property is to be avoided, the appropriation of which would cost more than the excavation; *third*, when the grade is at the maximum near a summit and cannot be raised parallel to itself without incurring too great an expense for masonry, etc., at some other part of the line. The embankment may be in excess, *first*, when the country is flat and wet, in order to keep the roadbed well drained (the grade line should be at least 2 ft above the average level of the surface, or above the high-water mark, if the district is subject to overflow); *second*, in approaching a stream, where it is necessary to raise the grade above the requirements of navigation; *third*, when the cuttings on the line are largely in solid rock, and a cheaper material for embankments may be conveniently used at other points; *fourth*, in a district subject to heavy drifts of snow by which deep cuts would be liable to be obstructed; *fifth*, in sidehill work, where there is danger of landslips; *sixth*, when it is determined to supply the place of a portion of an embankment by a timber trestlework or other viaduct.

The apparent equality of cut and fill on the profile does not represent an equality in fact, owing to the different bases and slopes of the sections adopted and to the various inclinations of the natural surface transverse to the line. This is especially true in sidehill work, where there are both cut and fill at every point, whereas the profile shows very little of either. In the latter case it is an excellent plan to combine with the profile of the center line the **profiles of parallel lines** 10 or 20 ft either side of the center, and drawn with different-colored inks, as these will indicate tolerably well the relative amount of cut and fill required. But after the grade has been thus chosen the only safe method in sidehill work is actually to compute the amounts of excavation and embankment from cross sections, mark the amount for each cut and fill on the profile, and compare the results. Any changes required in

the grade or alignment may then be discovered and effected before the work of construction has begun.

67. The grade contour. The grade contour is the line extending from one governing point to the next which follows the ground surface at the established uniform grade. The change of elevation of the grade contour is proportional to distance measured along the probable location of the finished line, rather than distance measured along the length of the grade contour itself where the intricacies of the ground surface

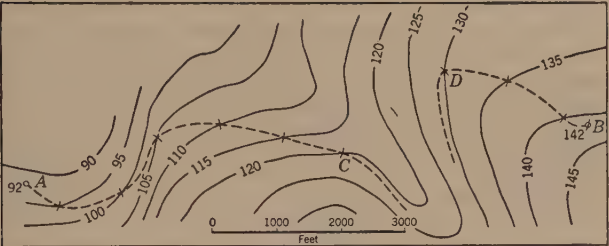


FIG. 8.

unduly increase its length. If the final line could follow the grade contour exactly, no cut or fill would be required other than leveling the roadbed laterally. The grade contour is drawn on the map as a guide to the position of the projected line.

To draw the grade contour proceed as follows (Fig. 8): Estimate the rate of the uniform grade between the two governing points from their difference in elevation and the traverse distance between them. Assume that the data for adjacent governing points *A* and *B* are the following:

Gov. Pt.	Plus	Elevation	Rate of Grade
<i>A</i>	30+00	92'	
<i>B</i>	130+00	142'	
Difference	10,000	+50'	+0.5%

To reach the 95-ft contour line the grade contour must rise 3 ft from point *A*. At a 0.5% grade the distance traversed must be 600 ft. Set a pair of dividers at 600 ft to scale. With *A* as a center, swing an arc intersecting the 95-ft contour in the direction the line is to follow, thus marking the

point on the 95-ft contour line through which the grade contour will pass. To reach the 100-ft contour from the 95-ft contour, the grade contour must rise 5 ft. At a 0.5% grade it must traverse a distance of 1000 ft. Set the dividers at 1000 ft and, with the point just marked as a center, swing an arc intersecting the 100-ft contour. The grade contour will cross the 100-ft contour line at this point. Continue this process until the elevation of point *B* is reached. Owing to errors in estimating the distance from the length of the

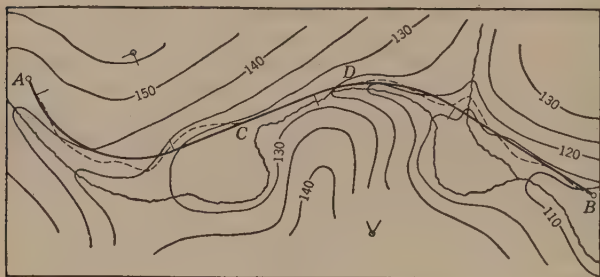


FIG. 9.

preliminary traverse, this point may fall short of or beyond point *B*. Adjust the positions of all the points plotted proportionally until it falls on *B*.

It is to be remembered that, when the grade contour crosses a small ravine or ridge, it may be necessary to step off the distance straight across the obstacle along the direction that the location line will take—rather than to follow the ravine or ridge. The grade contour will then disappear along the obstacle, and its intersection with one or two contour lines may be lost. It will return on the other side of the obstacle, and its exact position will be regained at the contour line corresponding to the distance stepped off. Note points *C* and *D* in Figs. 8 and 9.

After the points of intersection with the contour lines have been finally established, the grade contour is drawn connecting them. Between these points the grade contour must progress uniformly from one contour line to the next. For example, halfway between the points it must be halfway from one

contour line to the next. At the quarter points it must be one quarter or three quarters of the distance between the contours, and so on. The grade contour is sketched in according to this principle and inked usually by a dotted line.

68. Establishing the preliminary location line on the map. The location line is composed of straight lines (tangents) and usually the arcs of true circles (curves). Sometimes **spiral curves** are introduced (see Chapter IX) between arcs of different radii and between arcs and tangents. Since these change the location only very slightly, they are usually not considered until the actual track or pavement is laid out.

69. Radius of curvature. The minimum radius of curvature which can be used for railroads is the sharpest curve that can be negotiated by a road engine. It is in the neighborhood of 275 to 400 ft. Highway curves can be as sharp as required. However, in accordance with the principles covered in Chapter I, all curvature in general and sharp curves in particular should be avoided wherever the time loss they introduce is more expensive than the interest charges on the cost of their elimination. Where the topography requires an especially sharp curve, a careful economic study must be made before a decision can be reached. The practice of arbitrarily establishing a minimum curvature should be accepted only after a thorough investigation of the economics involved. In highway design, the introduction of a sharp curve where all other curves are of long radius should be avoided. It creates driver surprise and, therefore, constitutes a serious traffic hazard.

70. Separation between curves. Curves which turn in the same direction should be separated by a tangent at least 500 ft long. When the tangent is too short, the curve is called a **broken-backed curve**. Traffic traversing such a curve is subjected to a serious double roll. Broken-backed curves are usually easily avoided by bringing the two curves together or by substituting a longer radius curve for the two curves and their connecting tangent. Curves turning in opposite directions should be separated by a tangent at least 200 ft long. This gives room to run out the superelevation (gradually reduce the banking) and to introduce spirals. When high-speed operation is desired, these distances must be increased.

71. Plotting the line. A line consisting of curves and tangents is plotted on the map following the grade contour as

closely as possible except where special considerations previously described render this inadvisable. Many trials are often necessary to obtain the best approximation to the grade contour, and the work is greatly facilitated by using a black silk thread for establishing tangents and **curve templates** which are rules having edges curved at various radii for laying out curves. Sets of curve templates at various radii and scales may be purchased.

The black silk thread is attached to a pin placed at one governing point. The thread is extended beyond the next governing point and allowed to hang over the end of the drawing board. A light weight is attached to this end to keep the thread taut. The thread is then aligned with the straighter parts of the grade contour by placing pins at various positions. Various curve templates are tried between the tangents until those which most nearly fit the grade contour are found. Often the combination of tangents and curves must be changed many times to obtain the best fit (Fig. 9).

When the best line is thus established by inspection, it is penciled in and marked off in 100-ft stations. The depth of the cut or fill at each station is then estimated from the map by comparing the elevation of the ground at each station with the elevation of the adjacent point on the grade contour. By using the table of level sections (Table XXX; see also explanation Vol. II) or other means, the volume of the cut or fill for each station is estimated, and a mass-haul diagram is constructed. See Chapter XIV.

The original line is then adjusted to obtain the greatest economy in the balance of cuts, fills, and overhaul as indicated by the mass-haul diagram. Cuts are reduced by moving the line toward lower ground, and fills are reduced by moving it toward higher ground.

72. Data for the location survey. When the line is finally established on the map, certain data are taken off the map and recorded in a field notebook to be used in locating the line on the ground. The chief items are:

1. A list of offsets to each tangent.
2. The degree of curvature of each curve.

The offsets are scaled from the preliminary-survey traverse stations to the tangents. They are measured perpendicular

to the course in the traverse on which the station is located. Although only two offsets are necessary to locate a tangent, offsets from all preliminary-survey stations are usually recorded so that they will be available to facilitate avoiding obstacles in the field.

The degree of curvature measures the sharpness of a curve and, hence, is a function of the radius. See § 78. It is marked on each curve template. When the radius or the degree of curvature is known, the curve shown on the map can be reproduced in the field as soon as the tangents have been staked out. This procedure will result in placing the curve in the field in exactly the position indicated on the map.

CHAPTER IV

THE LOCATION SURVEY,

73. Staking out the tangents. The tangents are staked out by the transit party from the list of offsets. Usually two or three offsets near the end of each tangent are measured out with a metallic tape at estimated right angles from the preliminary traverse and marked by long stakes or range poles. Providing there are no blunders, the markers will stand in an approximately straight line, marking the position of the tangent. They will not be exactly in line, owing to the slight unavoidable errors of scaling the offsets. If the entire tangent can be seen from one end or the other, an average line is established by eye. A hub consisting of a stake and tack is set near each end of this line to give it definite position. No instrument is used in this process. The two hubs are set merely by directions from an observer looking along the line of markers. Each hub is called a **Point on Tangent**, abbreviated to P.O.T. A guard stake so marked is placed beside it.

If it is impossible to see the entire tangent from one end, offsets are marked near the ends as before, but auxiliary offsets are also laid out at the ends of the longest continuously visible section. A temporary hub is aligned by eye at each end of this section on the average line. Using a transit, the line marked by these temporary hubs is run out to the two ends of the tangent. From measurements between the temporary line and the average of the offsets at each end of the tangent, a new position is computed for the line which will carry it through the average position of all the offsets. The new position for the line is then run out with the transit and marked by permanent P.O.T.'s.

74. Field procedure for location. The work is begun by establishing the P.O.T.'s for at least the first and the second tangents. The position of the *first* tangent on the line is

usually determined by the connection that must be made. Accordingly, the P.O.T.'s for this tangent are usually established by precise measurements from existing objects or alignment stakes, rather than by offsets from the preliminary line.

A definite point is chosen to serve as station 0+00. Usually this is the point from which the preliminary survey originated. Beginning with this point, 100-ft stations are marked along the line of P.O.T.'s on the first tangent. Each station is marked by a hub consisting of a stake and tack and a guard stake is placed beside it. The stations are numbered continuously, beginning with station 0+00, throughout the entire line to the end. The station numbers are marked on the guard stakes. Stations are set along the first tangent until the next 100 ft falls beyond the second tangent projected backward.

At this point the procedure for staking out the curve is begun. This work is also carried out by the transit party. The procedure is described in Chapters V, VI, and XXI. The station measurement and enumeration are carried continuously around the curve and along the following tangent so that the stations set on the prolongation of the tangent beyond the beginning of the curve are abandoned. When the curve is completed, stations are set along the second tangent and at the same time P.O.T.'s are set on the third tangent. The process is repeated for the second curve and, in fact, throughout the whole line. P.O.T.'s must be set on the tangent ahead of each curve staked out. Usually several tangents are staked out at one time. The form of field notes is shown in Fig. 14.

The level party follows the transit party as closely as possible. This party obtains the profile of the location line and the cross section at each station, as described in Chapter X.

When the work of the transit party and level party is completed between two governing points, the final grade is established according to Chapter XVIII, the cross sections are drawn up, the quantities are computed, and the mass-haul diagram is constructed.

The mass-haul diagram will indicate any changes that may be required to improve the balance of the cuts and fills and to reduce the overhauls. Slight shifts in the line are used to

obtain these changes. The change in the quantity of cut and fill at any station caused by any lateral shift in the line can be computed from the cross section. The new position is drawn over the original ground profile shown in the cross section, and the new quantity is computed. The methods of changing the alignment for this purpose are covered in Chapter V and Chapter VI. These shifts will introduce stations which are not exactly 100 ft long. A record of these stations with their lengths must be kept readily available.

When the final line is completed the following operations take place:

1. All important hubs are witnessed so that they may be easily replaced if removed by construction.
2. The final grade is established if any changes have been made.
3. The slope stakes are set (see Chapter X) by which the positions and grades of the cuts and fills are marked for the contractor.
4. The boundary lines of all real-estate parcels to be acquired are run out and connected with the final line.
5. The final cross sections are drawn up from the data obtained by slope staking.
6. The final estimate is compiled by computing the quantities of all items and estimating their probable unit costs.
7. Finally, the contract drawings and specifications are made up.

75. Contract drawings. The most important contract drawings are the plans. These are made up by tracing the preliminary-survey map in standard-size sections after all the items to be constructed have been indicated on it. The chief survey data included are: the location center line showing stations and curve data and the right of way and property lines.

Usually the profile or profiles are placed on the same sheets as the plans. The profiles on each sheet refer to the section of line shown on that sheet. Elevations, rates of grade, and vertical curve data (see Chapter XVI) are shown on the profiles.

Additional drawings include a complete set of cross sections showing quantities for every station or half station, standard drawings of typical features like typical finished cross sec-

tions, typical small structures, typical track or pavement. Special drawings of larger structures are included, but usually large buildings or large bridges are contracted for separately and, therefore, form a separate set of plans.

76. Construction. During construction the engineer is required to see that the plans and specifications are followed. His duties are described in Chapter XV.

When the grading operations are complete, the track or pavement must be staked out. Most of the field work for this operation is similar to the field work of staking out the original center line. The additional procedures required are covered in Chapters VIII, IX, XVI, and XVII.

CHAPTER V

SIMPLE CURVES

ELEMENTARY RELATIONS

77. A simple curve is a circular arc joining two tangents. It is always considered as limited by the two tangent points, and any part of it beyond these points is called the curve produced. The first tangent point, or the point where the curve begins, is called the *Point of Curve*, and is indicated by the initials P.C. The point where the curve ends and the next tangent begins is called the *Point of Tangent* and is indicated by the initials P.T.

Notation sometimes used on railroads are *Beginning of Curve*, B.C., and *End of Curve*, E.C. The notations recommended by the American Railway Engineering Association are *Tangent to Curve*, T.C., and *Curve to Tangent*, C.T., for the beginning and end of the curve, respectively. The terms P.C. and P.T. are used in this book. When accessible, these points are always occupied by the transit in the course of the survey, and the plug driven to fix the point is guarded not only by the usual stake bearing the number of the station, but also by another bearing the proper initials, the "degree" of the curve, and an R or L to indicate whether the deflection is to the Right or Left.

78. A simple curve is designated either by the radius R or the degree of curve D .

The degree of curve D is a measure of the sharpness of the curve; the sharper the curve, the larger the D . Three slightly different definitions of D are found in practice: (1) the **metric** definition used with metric measurements, § 104; (2) the **arc** definition often found in American highway practice, § 404; and (3) the definition generally used in American and British railroad and highway practice which is stated in the next

paragraph and, except where noted, is used exclusively throughout this text.

The **degree of curve D** is an *angle at the center, subtended by a chord of 100 ft.* It is expressed by the number of degrees and minutes in that angle or in the arc of the curve limited by the chord of 100 ft.

The *radius R* and *degree of curve D* can be expressed in terms of each other.

Let ab , Fig. 10, be a chord of 100 ft subtending an arc described with a radius $aO = R$ from the center O . Then, by *definition* the angle $bOa = D$. Bisect the angle bOa by a line Og , and this line will also bisect the chord ab and be perpendicular to it; and in the right-angled triangle bgO



FIG. 10.

$$bg = Ob \times \sin bOg$$

or

$$\frac{100}{2} = R \sin \frac{1}{2}D$$

Hence, to find radius in terms of degree of curve,

$$R = \frac{50}{\sin \frac{1}{2}D} \quad (4)$$

or, approximately,

$$\frac{2\pi R}{360} = \frac{100}{D}$$

and

$$R = \frac{5730}{D} \quad (\text{approx.}) \quad (5)$$

where D is expressed in degrees.

To find degree of curve in terms of radius:

$$\sin \frac{1}{2}D = \frac{50}{R} \quad (6)$$

It is the practice of English engineers to assume the radius at some round number of feet and calculate the degree of

curve, which is therefore fractional. In America, on the contrary, the degree of curve is assumed at some integral number of degrees or minutes, and the radius deduced from this. With the sharp curves on electric railways, the radius is usually given.

Example 1. What is the radius of a $3^{\circ} 20'$ curve?

50	log	1.698970
$\frac{1}{2}D = 1^{\circ} 40'$	log sin	8.463665

Ans.	$R = 1719.12 \log$	3.235305
------	--------------------	----------

Thus, the second and third columns of Table I have been calculated, giving at once R or D in terms of the other.

Example 2. What is the degree of curve when the radius is 600 ft?

50	log	1.698970
$R = 600$	log	2.778151

$\frac{1}{2}D = 4^{\circ} 46' 48''.73$	log sin	8.920819
--	---------	----------

Ans.	$D = 9^{\circ} 33' 37''.46$
------	-----------------------------

Hereafter, unless specially directed, when D is given, R is to be taken from Table I and vice versa. However, when D is required to the nearest second, equation 6 should be used.

79. Stationing on curves. As stated previously, a **station** represents an increase in plus of 100 ft, and stationing is continuous throughout tangents and curves. Except where the line has been shifted from its original position, a *station on a tangent is 100 ft long*. On curves, however, the length of a station, although it *still indicates an increase in plus of 100 ft*, is measured, for convenience, in angular measure rather than in linear measure.

On all curves and under any definition of D , a **station** is an arc having the **angular length D** . The increase in plus equivalent to a station is similarly defined. A fractional station is a fractional part of the arc defined, and it is expressed by the same fractional part of the increase in plus that corresponds to a station.

Accordingly, if the definition of D which is standard for this text is used, on all curves a station is subtended by a **chord** of 100 ft, but the length of arc is slightly over 100 ft,

the amount increasing with the sharpness of the curve. In fractional stations the length of chord and the linear length of arc are *both* slightly greater than the number of feet used to indicate the increase in plus.

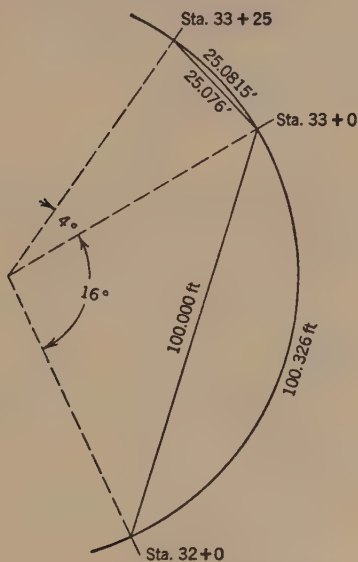


FIG. 11.

For example (Fig. 11), on a curve having $D = 16^\circ$, an increase of plus of 100 ft (one station) will be an arc of 16° , the chord will be 100 ft long, and the arc will have a length of 100.326 ft (Table IV). An increase in plus of 25 ft ($\frac{1}{4}$ station) will be an arc of 4° , the chord will be 25.076 ft long (Table VII), and the arc will be $\frac{1}{4} \times 100.326$ or 25.0815 ft in length. The methods of computation are given later.

80. The central angle of a simple curve is the angle at the center included between the radii which pass through the tangent points (P.C.) and (P.T.). It is therefore equal to the number of degrees contained in the entire arc of the curve between these points. The *central angle* will be designated by the Greek letter Δ (delta).

81. If two tangents, joined by a simple curve, are produced (one forward and the other backward) until they intersect, the point of intersection, V (Fig. 12), is called the **vertex** or **P.I.**, and the exterior or *deflection angle* which they make with each other is *equal* to the *central angle*, Δ .

82. The length of curve L is the increase in plus from the P.C. to the P.T.

By definition:

$$L = 100 \frac{\Delta}{D} \quad (7)$$

Example 1. What is the length of a 4° curve when the central angle is 29° ?

$$\begin{array}{l} D = 4^\circ \text{ and } \Delta = 29^\circ \\ \text{Ans. } L = 7 \text{ stations} + 25 \text{ ft} \end{array} \left\{ \begin{array}{l} 4 \overline{) 2900} \\ 725 \text{ ft} \end{array} \right.$$

Note. When Δ or D are not in exact decimals of a degree, reduce both values to minutes before dividing one by the other.

Example 2. What is the length of a $4^\circ 20'$ curve, when the central angle is $29^\circ 35'$?

$$\begin{array}{l} D = 260' \text{ and } \Delta = 1775' \\ \text{Ans. } L = 6 \text{ stations} + 82.69 \text{ ft} \end{array} \left\{ \begin{array}{l} 260 \overline{) 177500} \\ 682.69 \text{ ft} \end{array} \right.$$

To find the central angle in terms of the length and degree of curve:

Rearranging equation 7 gives

$$\Delta = \frac{DL}{100} \quad (8)$$

Example 3. What is the central angle of a 5° curve 730 ft long?

$$D = 5^\circ, \quad L = 730, \quad \frac{5 \times 730}{100} = 36^\circ.5$$

$$\text{Ans. } \Delta = 36^\circ 30'$$

To find the degree of curve in terms of the length and central angle:

Again, rearranging equation 7 gives

$$D = 100 \frac{\Delta}{L} \quad (9)$$

Example 4. What is the degree of a curve 8 stations long and having a central angle of $26^\circ 40'$?

$$L = 800, \quad \Delta = 1600', \quad 100 \frac{1600'}{800} = 200'$$

$$\text{Ans. } D = 3^\circ 20'$$

83. A **subchord** is any chord less than 100 ft. The **nominal length, b , of subchord** is the increase in plus covered by the subchord. The **length, c , of subchord** is the actual length of the subchord. The **subchord angle d** is the angular length of arc subtended by the subchord.

By definition:

$$d = \frac{b}{100} D \quad (10)$$

The expression for c is derived as follows.

From equation 6,

$$\sin \frac{1}{2} D = \frac{100}{2R}$$

Similarly,

$$\sin \frac{1}{2} d = \frac{c}{2R} \quad (11)$$

Dividing $\sin \frac{1}{2} d$ by $\sin \frac{1}{2} D$ results in

$$\sin \frac{1}{2} d = \frac{c}{100} \sin \frac{1}{2} D \quad (12)$$

and

$$c = 100 \frac{\sin \frac{1}{2} d}{\sin \frac{1}{2} D} \quad (13)$$

When D does not exceed 3° , we may assume without serious error that the *angles are to each other as their sines*. Hence,

$$(\text{Approx.}) \quad c = 100 \frac{d}{D} \quad (14)$$

and

$$c = b \quad (\text{approx.}) \quad (15)$$

In curves sharper than 3° per station, the error involved in this assumption becomes apparent and must be corrected.

To compute the value of c by equation 13 using logarithms requires arduous curvilinear interpolation. Since b is usually known, the following equation is used instead:

$$c = b + \text{correction} \quad (16)$$

The corrections are found in Table VII or may be more precisely computed as described in the next paragraph.

84. The correction for any given subchord bears an almost constant ratio to the excess of arc per station, whatever be the degree of curve. These ratios are shown in the following table for a series of subchords, and Table IV gives the length

TABLE OF THE RATIOS OF CORRECTIONS OF SUBCHORDS
TO THE EXCESS OF ARC PER STATION

Nominal Length of Subchord	Ratio	Nominal Length of Subchord	Ratio	Nominal Length of Subchord	Ratio
0	.000	35	.307	70	.356
5	.050	40	.336	75	.327
10	.099	45	.358	80	.287
15	.147	50	.374	85	.235
20	.192	55	.383	90	.169
25	.234	60	.383	95	.092
30	.273	65	.374	100	.000

of actual arc per station for various degrees of curve. Subtracting 100, we have the excess of arc per station, and, multiplying this *excess* by the *ratio* corresponding to the nominal length of subchord, we obtain as a product the proper correction for the subchord. Both this excess and the ratio are also given in Table VII.

We observe that the largest correction is required by a subchord between 55 and 60 ft in length.

Example 1. It is proposed to run a 14° curve with a 50-ft chain. What correction must be added to the chain?

$$D = 14^\circ, \quad \frac{1}{2}D = 7^\circ, \quad \frac{1}{2}d = \frac{50}{100} \times 7^\circ = 3^\circ.5 = 3^\circ 30'$$

By equation 13,

$$c = 100 \frac{\sin 3^\circ 30'}{\sin 7^\circ} = 50.093$$

Ans. Correction = 0.093

or, by Table VII, Length of arc = 100.249

Excess of arc = 0.249

and, by Table VII, Ratio for 50 ft = 0.374

Ans. Correction = product = 0.093

Example 2. The P.C. of an 18° curve is fixed at +55 ft beyond a station. What are the nominal and true values of the first subchord, and what is the proper deflection?

Nominal value = $100 - 55 = 45$ ft

Deflection = $\frac{1}{2}d = \frac{45}{100} \times 9^\circ = 4^\circ.05 = 4^\circ 03'$

and, by equation 13,

True value = $c = 100 \frac{\sin 4^\circ 03'}{\sin 9^\circ} = 45.148$

or, by Table VII, Excess of arc = 0.412

and, by Table VII, Ratio for 45 ft = 0.358

Correction = product = 0.147

Ans. True value of subchord = 45.147

Example 3. The last deflection at the end of a 40° curve is found to be $6^\circ 30'$. What are the nominal and true values of the last subchord?

Here $\frac{1}{2}d = 6^\circ 30'$, and, by equation 14,

Nominal value, $c = 100 \frac{6.5}{20} = 32.5$ ft

By equation 13,

True value, $c = 100 \frac{\sin 6^\circ 30'}{\sin 20^\circ} = 33.098$ ft

or, by Table VII, Excess of arc $40^\circ = 2.060$

and, by Table VII, Ratio for 32.5 ft = 0.290

Correction = product = 0.597
 Nominal value of subchord = 32.5

True value = 33.097

Table VII precludes most of the labor involved in computing the corrections to subchords.

85. The tangent distance T is the distance from the vertex to either tangent point; thus, in Fig. 12, $T = AV = VB$.

86. The long chord C is the line AB joining the two tangent points.

87. The middle ordinate M is the line GH joining the middle point of the long chord with the middle point of the curve.

88. The external distance E is the line HV joining the middle point of the curve with the vertex.

We observe that both the middle ordinate M and the external distance E are on the radial line joining the center O with the vertex V and that this line is perpendicular to the long chord C ; also, that it bisects the central angle $AOB = \Delta$ and its supplement AVB (Table XLI, 14). We also observe that the angle $VAB = VBA = \frac{1}{2}\Delta$ (Table XLI, 20); and, if in the figure we draw the two chords AH and BH , the angle BAH equals one-half the angle BOH , or $BAH = ABH = \frac{1}{4}\Delta$ (Table XLI, 18); also, the angle $VAH = VBH = \frac{1}{4}\Delta$.

89. If we have laid out two tangents on the ground intersecting at V and have measured the angle Δ between them, we may then assume any other one of the elements of a simple curve before mentioned and calculate the rest. If we assume D , for instance, we then find R by equation 4 or by Table I.

Then, having Δ and R , we may proceed to calculate the other elements as they are needed.

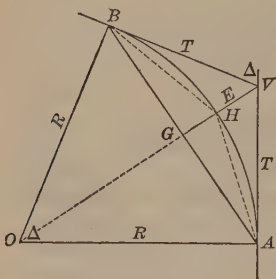


FIG. 12.

90. To find the tangent distance in terms of the radius and central angle:

In the right-angled triangle VOA , Fig. 12, we have

$$VA = OA \times \tan VOA$$

$$T = R \tan \frac{1}{2}\Delta \quad (17)$$

Otherwise, approximately:

In Table III, opposite the central angle, take the value of T for a 1° curve, and divide it

by the degree of curve D . If desirable, add the correction taken from Table II, corresponding to D .

Example. What is the tangent distance of a 4° curve with a central angle of 30° ?

$$\begin{array}{llll} D = 4^\circ, & R \text{ (Table I) } \log & 3.156151 \\ \Delta = 30^\circ, & \frac{1}{2}\Delta = 15^\circ \log \tan & 9.428052 \end{array}$$

$$\text{Ans. } T = 383.89 \text{ ft} \qquad \log \quad 2.584203$$

Otherwise:

$$\begin{array}{ll} \text{By Table III,} & 4 \overline{)1535.3} \\ \text{Approximate answer,} & 383.82 \\ \text{Correction from Table II,} & 0.08 \end{array}$$

$$\text{Ans. } T = 383.90 \text{ ft}$$

91. To find the long chord C , in terms of radius and central angle:

In the right-angled triangle BOG , Fig. 3, we have

$$BG = BO \times \sin BOG$$

or

$$\frac{1}{2}C = R \sin \frac{1}{2}\Delta$$

$$C = 2R \sin \frac{1}{2}\Delta \qquad (18)$$

But, in case Δ can be divided by D without a remainder, that is, if the curve contains an exact number of stations (not exceeding 12), we may take the long chord at once from Table IV.

Example. What is the long chord of a $3^\circ 20'$ curve with a central angle of $36^\circ 40'$?

$$\begin{array}{llll} & 2 & \log & 0.301030 \\ D = 3^\circ 20', & R \text{ (Table I) } \log & 3.235305 \\ \Delta = 36^\circ 40', & \frac{1}{2}\Delta = 18^\circ 20' \log \sin & 9.497682 \end{array}$$

$$\text{Ans. } C = 1081.48 \text{ ft} \qquad \log \quad 3.034017$$

Otherwise:

$$\frac{\Delta}{D} = \frac{36\frac{2}{3}^\circ}{3\frac{1}{3}^\circ} = 11 \text{ stations}$$

and, by Table IV, $C = 1081.48$.

92. To find the middle ordinate M , in terms of radius and central angle:

From Fig. 12,

$$M = GH = OH - OG = R - R \cos \frac{1}{2}\Delta$$

or

$$M = R(1 - \cos \frac{1}{2}\Delta)$$

and, since the versine = $1 - \cos$ ine,

$$M = R \text{ vers } \frac{1}{2}\Delta \quad (19)$$

But, in case Δ can be divided by D without a remainder, that is, if the curve contains an exact number of stations (not exceeding 12), we may take the middle ordinate at once from Table VI.

Example. What is the middle ordinate of a $4^\circ 30'$ curve with a central angle of $40^\circ 30'$?

$$\begin{array}{llll} D = 4^\circ 30', & R \text{ (Table I)} & \log & 3.105022 \\ \Delta = 40^\circ 30', & \frac{1}{2}\Delta = 20^\circ 15' & \log \text{ vers } & 8.791049 \end{array}$$

$$\text{Ans. } M = 78.717 \text{ ft} \quad \underline{1.896071}$$

Otherwise:

$$\frac{\Delta}{D} = \frac{40.5}{4.5} = 9 \text{ stations}$$

and, by Table VI, $M = 78.717$.

For additional formulas for the middle ordinate, see Chapter XVI, Track Laying.

93. To find the external distance E , in terms of radius and central angle:

From Fig. 12,

$$E = VH = VO - HO$$

or

$$E = \frac{R}{\cos \frac{1}{2}\Delta} - R = R \left(\frac{1}{\cos \frac{1}{2}\Delta} - 1 \right)$$

and, since the ex sec = secant - 1, we have,

$$E = R \text{ ex sec } \frac{1}{2}\Delta \quad (20)$$

Otherwise, approximately:

In Table III, opposite the central angle, take the value of E for a 1° curve, and divide it by the degree of curve D . If desirable, add the proper correction corresponding to D , taken from Table II.

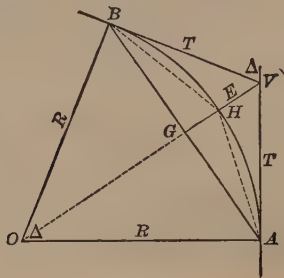


FIG. 13.

Example. What is the external distance E of a $7^\circ 30'$ curve when the central angle is 60° ?

$$\begin{array}{ll} D = 7^\circ 30', & R \text{ (Table I) } \log \quad 2.883371 \\ \Delta = 60^\circ, & \frac{1}{2}\Delta = 30^\circ \quad \log \text{ ex sec } 9.189492 \end{array}$$

$$\text{Ans. } E = 118.27 \text{ ft} \quad \log \quad 2.072863$$

Otherwise:

$$\begin{array}{ll} \text{By Table III,} & 7.5)886.38 \\ \text{Approximate answer,} & 118.184 \\ \text{Correction for } D = 7^\circ 30' \text{ (Table II),} & 0.084 \end{array}$$

$$\text{Ans. } E = 118.268$$

94. But, instead of assuming D or R , we may prefer or may find it necessary to assume some other element of the curve, the central angle being given.

If we assume the tangent distance, then:

95. To find the radius and degree of curve in terms of the tangent distance and central angle.

From equation 17, and by Table XLII, 40, we have

$$R = T \cot \frac{1}{2}\Delta \quad (21)$$

Otherwise, approximately:

Divide the tangent of a 1° curve found opposite the value of Δ in Table III, by the assumed tangent distance; the quotient will be the degree of curve in degrees and decimals.

Example. The exterior angle at the vertex is 54° , and the tangent distance must be about 700 ft. What will be the degree of curve?

$$\begin{array}{rcl} \Delta = 54^\circ, & \frac{1}{2}\Delta = 27^\circ \log \cot & 0.292834 \\ T = 700 & & 2.845098 \\ \hline \log R = & & 3.137932 \end{array}$$

Ans. By Table I, $D = 4^\circ 10' +$

Otherwise:

$$\begin{array}{rcl} & \text{By Table III, } 700)2919.4 & \\ \text{Ans. } D = 4^\circ 10' 15'' & & 4.1706 \end{array}$$

But, as it is difficult to lay out a curve when D is fractional, we discard the fraction and assume $4^\circ 10'$ as the value of D . This may require us to recalculate the value of T , which we do by equation 17 and find $T = 700.8$ ft log 2.845596. If the other elements are required, they may be calculated by equations 18, 19, 20, or directly from T and Δ , as follows:

96. To find the external distance E , in terms of the tangent distance and central angle.

In Fig. 13 we have given $AOB = \Delta$ and $AV = T$, to find $HV = E$. The angle $VAH = HAG = \frac{1}{4}\Delta$.

In the triangle AVH ,

$$AV:HV::\sin VHA:\sin VAH$$

Now,

$$VHA = 180^\circ - AHO = 180^\circ - (90^\circ - \frac{1}{4}\Delta) = 90^\circ + \frac{1}{4}\Delta$$

$\therefore$

$$\sin VHA = \sin (90^\circ + \frac{1}{4}\Delta) = \cos \frac{1}{4}\Delta$$

Substituting

$$T:E::\cos \frac{1}{4}\Delta:\sin \frac{1}{4}\Delta$$

and solving, we have

$$E = T \tan \frac{1}{4}\Delta \quad (22)$$

Example. The angle at the vertex being 54° and the tangent distance 700.80 ft, how far will the curve pass from the vertex?

$$\begin{aligned} T &= 700.80 \text{ (from last example)} & 2.845596 \\ \Delta &= 54^\circ, \quad \frac{1}{4}\Delta = 13^\circ 30' & \log \tan 9.380354 \end{aligned}$$

$$\text{Ans. } E = 168.25 \text{ ft} \qquad \log 2.225950$$

(For the formulas by which to find the long chord and middle ordinate in terms of the tangent distance and central angle, see Table XLIII, 12 and 13.)

97. Again, it may be necessary to assume the *external distance* in order to determine the proper degree of curve.

To find the radius and degree of curve in terms of the external distance and central angle:

By equation 20,

$$R = \frac{E}{\text{ex sec } \frac{1}{2}\Delta} \qquad (23)$$

Otherwise:

In Table III divide the external distance of a 1° curve, opposite the given value of Δ , by the assumed external distance; the quotient is the degree of curve required.

Example. The angle at the vertex being $24^\circ 30'$, the curve is desired to pass at about 65 ft from the vertex. What is the proper degree of curve?

$$\begin{aligned} E &= 65 & \log & 1.812913 \\ \Delta &= 24^\circ 30', \quad \frac{1}{2}\Delta = 12^\circ 15' & \log \text{ex sec} & 8.367345 \\ \log R &= & & 3.445568 \end{aligned}$$

$$\text{Ans. By Table I, } D = 2^\circ 03' +$$

Otherwise:

$$\begin{aligned} &\text{By Table III, } 65 \overline{)133.50} \\ \text{Ans. } D &= 2^\circ 03' 14'' & 2^\circ.0538 \end{aligned}$$

We may therefore assume a 2° curve, unless required by the circumstances to be more exact, when we might use a $2^\circ 03'$ curve. Assuming a 2° curve, we have, by equation 20,

$$E = 66.75 \log 1.824460$$

Having decided on the degree of curve, we may calculate the remaining elements by equations 17, 18, and 19. But, if desired, we may calculate them directly from E and Δ .

98. *To find the tangent distance, in terms of the external distance and central angle:*

From equation 22, and by Table XLII, 40,

$$T = E \cot \frac{1}{4}\Delta \quad (24)$$

Example. The angle at the vertex is $24^\circ 30'$, and the curve passes 66.75 ft from the vertex. How far are the tangent points from the vertex?

$$E = 66.75 \text{ (from last example)} \quad \log \quad 1.824460$$

$$\Delta = 24^\circ 30', \quad \frac{1}{4}\Delta = 6^\circ 07' 30'' \quad \log \cot \quad 0.969358$$

$$\text{Ans. } T = 622.04 \text{ ft} \quad 2.793818$$

LOCATION OF CURVES BY DEFLECTION ANGLES

99. Except under unusual conditions, the best procedure for locating a curve is the method of deflection angles. This method is based chiefly on the following geometric principle.

An angle between two chords, or between a chord and a tangent, which intersect at the circumference of a circle, is measured by one-half the intercepted arc.

In accordance with §§ 73 and 74, the procedure for staking out the curve begins after the tangent previous to the curve (the back tangent) and the tangent following the curve (the forward tangent) have both been marked by P.O.T.'s and the back tangent has been staked out in stations to a point within 100 ft of the probable position of the P.I.

100. The 12 steps followed in staking out a curve by deflection angles. The steps for locating a curve by deflection angles are here described. They are illustrated by the computations required for an actual 16° curve. The resulting field notes and a sketch of the curve are shown in Fig. 14.

1. **Set the P.I.** Two hubs are set on the *back* tangent as near together as possible but so that the P.I. will fall between them, and a string is stretched between the two tacks. A hub is then set under the string in line with the *forward* tangent.

2. **Measure the plus of the P.I.** Measure the plus from the last station on the back tangent to the P.I. Assume the resulting plus of the P.I. to be $65+27.42$.

3. **Measure Δ .** The deflection angle between the two tangents at the P.I. is measured by repetition. Usually the interior angle is turned four times (2 D.R.) and the result subtracted from 180° . Assume $\Delta = 72^\circ 35' 15''$.

4. **Compute T .** $T = R \tan \frac{1}{2}\Delta$, and check by special table (§ 90).

$$\begin{array}{rcl}
 \log R = 2.555415 & \text{By Table III,} & 16)4207.90 \\
 \log \tan 36^\circ 17' 37''.5 = 9.865936 & \text{Approx. answer,} & 262.99 \\
 \log T = 2.421351 & \text{Corr. Table II,} & + 0.85 \\
 & & \hline
 T = 263.85 & T & = 263.84
 \end{array}$$

5. **Compute the plus of the P.C.** T is subtracted from the plus of the P.I.

$$\begin{array}{rcl}
 \text{Plus of P.I.} & = & 65+27.42 \\
 \text{Less } T & = & - 263.85 \\
 & & \hline
 \text{Plus of P.C.} & = & 62+63.57
 \end{array}$$

6. **Compute L .** $L = 100\Delta/D$. Convert Δ and D into minutes and decimal parts of a minute.

$$L = 100 \frac{4355.25}{960} = 453.67$$

7. **Compute the plus of the P.T.** L is added to the plus of the P.C.

$$\begin{array}{rcl}
 \text{Plus of P.C.} & = & 62+63.57 \\
 \text{Add } L & = & 453.67 \\
 & & \hline
 \text{Plus of P.T.} & = & 67+17.24
 \end{array}$$

8. **Compute the list of deflection angles.** If possible the curve is staked out with the transit at the P.C. The proper deflection angle is turned from the P.I. (that is, from the forward direction of the back tangent) to each station on the curve, and chords are measured, first from the P.C. to the

first station on the curve, then from the first station to the second station, and so on. Even if it is impossible to stake out any or all of the curve in this manner, the list of deflection

FORM OF TRANSIT BOOK

Sta.	Chord	Deflec.	Curve Data	Dist.	Cal. Bear
68+0 +17.24 P.T. 67+0	17.29 100.00	36° 17' 37" 34° 54' 52"	D=16° L Δ=72° 35' 15" ½Δ=36° 17' 37.5" T=263.85 L=453.67		
66+0 +27.42 P.I. 65+0	100.00 100.00	26° 54' 52" 18° 54' 52"			
64+0	100.00	10° 54' 52"			
63+0 +63.57 P.C. 62+0	36.53	2° 54' 52"			

Computations

$$\begin{aligned}
 L R &= 2.555415 \\
 L \tan 36^\circ 17' 37.5'' &= 9.865936 \\
 L T &= 2.421351 \\
 T &= 263.85 \\
 \text{Plus P.I.} &= 6527.42 \\
 \text{Plus P.C.} &= 6263.57 \\
 L &= 453.67 \\
 \text{Plus P.T.} &= 6717.24
 \end{aligned}$$

$$\begin{aligned}
 \text{Plus 1st Sta} &= 6300.00 \\
 \text{Plus P.C.} &= 6263.57 \\
 b &= 36.43 \\
 &= 480 \\
 &= 291.44
 \end{aligned}$$

$$\begin{aligned}
 \frac{1}{2}d &= 174.8640' \\
 \frac{1}{2}d &= 2^\circ 54' 52''
 \end{aligned}$$

$$\Delta = 4320' + 35.25' = 4355.25'$$

$$D = 960' \quad \frac{1}{2}D = 480'$$

$$L = 453.67$$

$$96.0 \overline{) 4355.25}$$

$$\begin{array}{r}
 384 \\
 \underline{515} \\
 480 \\
 \underline{352} \\
 288 \\
 \underline{645} \\
 576 \\
 \underline{690} \\
 672
 \end{array}$$

$$b' = 17.24$$

$$480$$

$$13792$$

$$6396$$

$$\frac{1}{2}d' = 82.7520'$$

$$\frac{1}{2}d' = 1^\circ 22' 45''$$

$$34 \quad 54 \quad 52$$

$$\text{Deflec. of P.T.} = 36^\circ 17' 37''$$

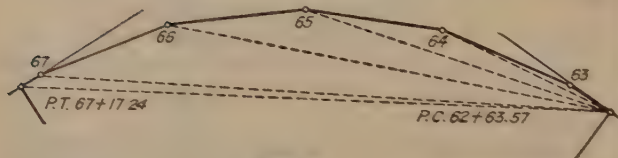


FIG. 14.

angles is always computed since (as is shown later) they are always used.

The increase in plus from the P.C. to the first station on the curve is computed first. This is b , the nominal length of the

subchord measured from the P.C. In this case, the first station on the curve is 63+0.

$$\text{Plus of first station} = 63+00.00$$

$$\text{Less plus of P.C.} = 62+63.57$$

$$b = 36.43$$

The increase in plus from the last station on the curve 67+0 to the P.T. at 67+17.24 is computed. Call this b' .

$$\text{Plus of P.T.} = 67+17.24$$

$$\text{Less plus of last station} = 67+00.00$$

$$b' = 17.24$$

The angle of the arc subtended by the subchord b extending from the P.C. is d . The deflection angle at the P.C. is measured by one-half this arc.

From equation 10,

$$\frac{1}{2}d = \frac{1}{2} \frac{b}{100} D \quad (25)$$

This equation may also be written:

$$\frac{1}{2}d = 0.3bD \quad (26)$$

where d is in minutes and D is in degrees.

Compute $\frac{1}{2}d$, the deflection angle at the P.C. to the first station on the curve.

$$\frac{1}{2}d = \frac{1}{2} \cdot \frac{36.43}{100} 960' = 174.864 \text{ minutes}$$

$$\frac{1}{2}d = 2^\circ 54' 52''$$

The angle of the arc from the first station on the curve to the second station on the curve is D . The increase in the deflection angle from the first to the second station is $\frac{1}{2}D$, etc.

$$\frac{1}{2}D = 8^\circ$$

Compute the remaining deflection angles by adding $\frac{1}{2}D$ successively.

Station	Deflection
P.C.	0
63	2° 54' 52"
	+8
64	10 54 52
65	18 54 52
66	26 54 52
67	34 54 52

Compute the increase in the deflection angle from the last station to the P.T.

$$\frac{1}{2}d' = \frac{1}{2} \frac{17.24}{100} 960' = 82.752 \text{ minutes}$$

$$\frac{1}{2}d' = 1^{\circ} 22' 45''$$

Compute the deflection angle of the P.T. by adding $\frac{1}{2}d'$ to the deflection angle of the last station.

$$\begin{array}{r} 67 \quad 34^{\circ} 54' 52'' \\ + \quad 1 \quad 22 \quad 45 \\ \hline \text{P.T.} \quad 36^{\circ} 17' 37'' \end{array}$$

The deflection angle to the P.T. should equal $\frac{1}{2}\Delta$ as the arc subtended equals Δ . Since $\frac{1}{2}\Delta = 36^{\circ} 17' 37''.5$, the list of deflection angles checks. The deflection angles are computed with the high precision to obtain this check. They are not set with this precision.

Compute the true length c and c' of the subchords.

$$c = b + \text{correction}$$

$$\begin{array}{rcl} b = & 36.43 \text{ ft} & b' = 17.24 \text{ ft} \\ \text{Corr. (table)} = & + 0.10 \text{ ft} & \text{Corr. (table)} = + 0.05 \text{ ft} \\ \hline c = & 36.53 \text{ ft} & c' = 17.29 \text{ ft} \end{array}$$

9. **Set the P.T.** Set a hub in line with the P.O.T.'s on the forward tangent at a distance T (263.85 ft) from the P.I.

10. **Set the P.C.** Set a hub on line with the P.O.T.'s on the back tangent and at the correct distance (63.57 ft) from the station previous to the P.C. (sta. 62+00).

11. Run curve. Set up at the P.C. Orient the transit by pointing the P.I. with the vernier at zero. Turn off the deflection angle to the first station as nearly as may be set on the vernier ($2^{\circ} 54' 45''$). Measuring c (36.53 ft) from the P.C., set a hub on line (sta. 63+0).

Turn to the next deflection angle ($10^{\circ} 54' 45''$), and, measuring 100 ft from the first station (63+0) set the second station (64+0) on the line established by the transit.

Continue setting each station by measuring 100 ft from the previous station and taking alignment from the transit which has been set each time at the proper deflection angle for the station being established.

12. Check at the P.T. for line and distance. When the last station has been set (sta. 67+0), measure the distance from it to the P.T. already located. Assume that this is 17.16. The difference between this and c' is the error in distance.

$$\begin{array}{rcl} c' & = & 17.29 \text{ ft} \\ \text{Meas.} & = & 17.21 \text{ ft} \\ \hline \text{Diff.} & = & 0.08 \text{ ft} \end{array}$$

Turn off the deflection angle of the P.T., and measure how far to one side of the P.T. the line falls. This is the error in line. Assume 0.06 ft.

The total error is the square root of the sum of the squares of the errors, or 0.10 ft. This value divided by the total length of the survey is the measure of accuracy. In most work of this kind the accuracy should be better than 1 part in 3000. The total length of the survey is $2T+L$.

$$\text{Accuracy} = \frac{0.10}{981.37} = \frac{1}{9814}$$

When a Setup on the Curve is Necessary

101. Geometry. In Fig. 15, it may be noted that

$$\angle VPB = \frac{1}{2} \text{ arc } PAB$$

$$\angle MAB = \frac{1}{2} \text{ arc } PAB$$

(The last statement is obvious when a tangent is constructed at A .)

$$\therefore \angle MAB = \angle VPB$$

But $\angle VPB$ is the deflection angle of B . Therefore, if a transit is placed at A and oriented by sighting P with the vernier at zero and the telescope reversed, the direction to B

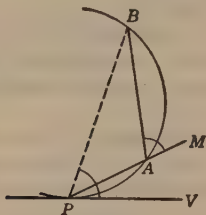


FIG. 15.

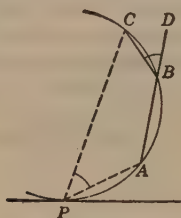


FIG. 16.

can be obtained by laying off its deflection angle and sighting with the telescope direct.

In Fig. 16, it may be noted that

$$\angle DBC = \angle APC$$

(Both are measured by $\frac{1}{2}$ the same arc, ABC .)

But $\angle APC$ represents the difference in the deflection angles of A and C . Therefore, if a transit is placed at B and oriented by sighting A with the vernier at the deflection angle of A and with the telescope reversed, the direction of C can be found by laying off its deflection angle with the telescope direct. This process adds the difference of the deflection angles of A and of C to the deflection angle of A .

It should also be noted that these processes are reversible. For example, in Fig. 16, the transit might have been oriented by sighting C with the telescope direct and the vernier set at the deflection angle of C . Then the direction of A can be established by turning to the deflection of A and sighting with the telescope reversed.

If we assume that the deflection angle of the P.C. is zero and that forward sights are made with the telescope direct and backward sights with the telescope reversed, a general rule may be stated.

When the transit is set up on the curve, if the vernier reads the deflection of one curve point sighted, it will read the deflection of every curve point sighted. A transit so placed and oriented is said to be **oriented to the curve**.

It should be further noted that, when the transit is oriented to the curve, if the vernier is set at the deflection of the point occupied by the transit, the line of sight will be tangent to the curve.

When it is suspected that the transit is out of adjustment, instead of reversing the telescope when making a backsight, 180° is added to the usual vernier setting.

102. Procedure. By using these principles, it is possible to run a curve which is only partly visible from the P.C. When the curve has been run as far as possible, the transit is moved forward to another point on the curve, oriented, and the curve continued (Fig. 17). The points at which the transit is set up are called **Points on Curve** or P.O.C.'s. Usually stations are used. P.O.C.'s are marked in the notes by circles with dots in the center. When a point other than a station is chosen, the most desirable plus is selected, and the deflection angle and the subchord lengths are computed. The transit is usually oriented at a P.O.C. by sighting another P.O.C. rather than any convenient station.

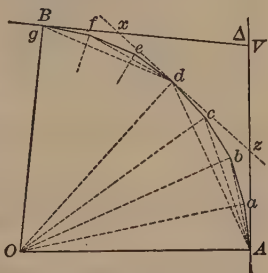


FIG. 17.

Some engineers prefer not to use the original set of deflection angles when a transit is moved forward, but instead elect to set the vernier so that it will **read zero on the local tangent**. This is accomplished by pointing at any back station with the vernier set at the difference between the deflection angle of that station and the deflection angle of the station occupied, but turned in the opposite direction to the direction of the curve. For example, on an 8° left curve when the transit is set up at station 65 and is to be sighted at station 62, the vernier would be set at 12° clockwise. Each succeeding forward station can be set by turning a multiple of $\frac{1}{2}D$ from the tangent.

103. The stations on a curve may be located by deflections only, without linear measurements. For this purpose two transits are set at two transit points on the curve, as *A* and *B*, Fig. 18, and the proper deflections for any station are made with both instruments, the station being located by finding the intersection of the two lines of collimation.

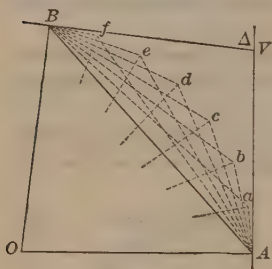


FIG. 18.

degree of curve D_m is the angle of arc subtended by one station.

The tape ordinarily used is 20 meters long (65.617 ft), and, since the odd-numbered stations are unnecessary for most work, they are seldom set. Curves are staked out by chords 20 meters long, each of which subtends exactly two stations. Accordingly the deflection angle for each chord is equal to the degree of curvature D_m .

Therefore,

$$\sin D_m = \frac{10}{R_m}$$

and

$$R_m = \frac{10}{\sin D_m} \quad (27)$$

The values for R_m given in Table XI have been computed by this formula and the values for m_m and t_m similarly.

If values are required for curves not listed, Table I can be used with certain changes. For example, the values for R have been computed as follows:

$$R = \frac{50}{\sin \frac{1}{2}D}$$

Equation 27 can be solved by this formula (and, hence, the value of R_m determined) by entering Table I with twice the value of D_m and dividing the result by 5.

The same procedure will give *approximate* values for T_m , C_m , and M_m in Tables III, IV, and VI, respectively. The values are not exact as this procedure involves the assumption that the following approximate formula is correct:

$$\frac{\sin \frac{1}{2}D}{\sin D} = \frac{1}{2} \quad (\text{approx.})$$

105. Relining an existing curve. *String lining*, described in Chapter XVII, is the best method for relining existing track. When it is necessary to establish a truly circular curve that will coincide closely with an existing nearly circular curve, equations 23 and 24 are particularly useful.

Produce the center lines of the tangents of the curve to an intersection V , and there measure the angle Δ . Bisect its supplement AVB , and measure the distance on the bisecting line from V to the center line of the track. This will give $VH = E$. Then, R and T may be calculated, and the distance T laid off from V on the tangents, giving the tangent points A and B .

Or, select the point which appears to be the P.C. of the curve. Measure $VA = T$. Solve equation 21 and, taking D to the nearest minute, solve equation 17 for T . Reline the curve, and, if the P.C. has been well selected and if the curvature is regular, the new stakes should agree fairly well with the original center line.

(For the formulas by which to find the long chord and middle ordinate in terms of E and Δ , see Table XLIII, 26 and 27.)

Again, having only the central angle given, we may assume the long chord or the middle ordinate and from either of these and the central angle calculate the remaining elements. Or, finally, the central angle being *unknown*, we may suppose any two of the linear elements given and from these calculate the rest. As such problems have little practical value, discussion of them is omitted. The requisite formulas for their solution are given in Table XLIII.

LOCATION OF CURVES BY OFFSETS

106. A curve may be located by linear measurement only, without angular deflections. There are four general methods, namely:

By offsets from the chords produced.

By offsets from the tangents.

By middle ordinates.

By ordinates from a long chord.

To Locate a Curve by Offsets from the Chords Produced

When the curve begins and ends at a station.

107. Let *A*, Fig. 19, be the P.C. of a curve taken at a station, to locate the other stations, *a*, *b*, *c*, etc. The chords *Aa*, *ab*, *bc*, etc., each equal 100 ft, and, since the angle $\angle AOa = D$, the angle $\angle VAa = \frac{1}{2}D$. Taking an offset $ax = t$, perpendicular to the tangent, we have in the right-angled triangle *Axa*:

$$ax = Aa \times \sin \frac{1}{2}D$$

or

$$t = 100 \sin \frac{1}{2}D \quad (28)$$

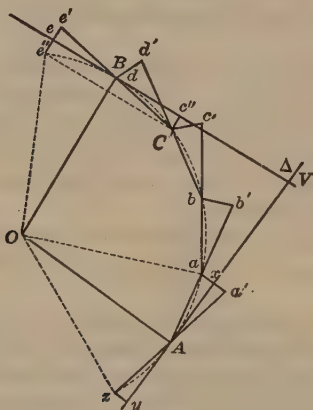


FIG. 19.

The offset *t* is called the tangent offset, and its value is given for all degrees of curve in Table I, column 4. Natural sines should be used in solving this formula.

If the curve were produced backward from A , 100 ft to station z , the offset zy would equal t ; and, if the chord zA were produced 100 ft from A to a' , the offset $a'x$ would also equal t . Therefore the distance $aa' = 2t$, and the angle $aAa' = D$. So, if we produce the chord Aa 100 ft to b' , the distance $bb' = 2t$.

To lay out the curve, stretch the tape from A , keeping the forward end at a perpendicular distance t from the line of the tangent to locate station a . Then find the point b' by stretching the tape from a in line with a and A , and, then, stretching the tape again from a , fix its forward end at a distance from b' equal to $2t$. This gives station b . In the same way find other stations.

When the last station, as d , of the curve is reached, produce the curve one station farther to e'' . Then the tangent through d is parallel to the chord ce'' , and, if t is laid off from c and e'' perpendicular to this chord, the tangent $c'e$ is found. If the work has been correctly done, the tangent $c'e$ will coincide with the given tangent VB .

When the curve begins and ends with a subchord:

108. Let A , Fig. 20, be the P.C. and Aa the first subchord $= c$, and the angle $V A a = \frac{1}{2}d$, and let the offset $ax = t_1$. Then,

$$t_1 = c \sin \frac{1}{2}d \quad (29)$$

Producing the curve backward to the nearest station z , we have another subchord $Az = (100 - c)$, and the angle $yAz = \frac{1}{2}(D - d)$, and, putting the offset $yz = t_2$,

$$t_2 = (100 - c) \sin \frac{1}{2}(D - d) \quad \text{approx.} \quad (30)$$

Laying off the two subchords on the ground and making the proper offsets t_1 and t_2 at the same time, we fix the position of the two stations a and z on the curve; after which we may produce the chord za 100 ft to b' and proceed as before until the curve is finished.

If the curve ends with a subchord, as dB , produce the curve to the first station beyond B , as e'' , then calculate the two offsets for the two subchords Bd and Be'' , and lay them off from d and e'' perpendicular to the supposed direction of the tangent. If the line $d''e$ so obtained coincides with the given tangent VB , the work is correct.

109. We may find the values of t_1 and t_2 otherwise than by the preceding formulas, for in Fig. 19 we have shown that the angle $aAa' = aOA$, and, since these triangles are isosceles, they are similar; therefore:

Fig. 19, $OA:Aa::Aa:aa'$

$$R:100::100:2t$$

$\therefore$

$$t = \frac{(100)^2}{2R} \quad (31)$$

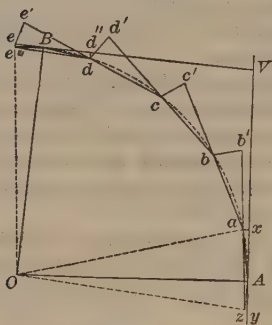


FIG. 20.

and, similarly, Fig. 20,

$$t_1 = \frac{c^2}{2R} \quad (32)$$

Hence:

$$t_1:t::c^2:(100)^2$$

$\therefore$

$$t_1 = \frac{c^2 t}{(100)^2} \quad (33)$$

Thus, t_1 may be found by multiplying the square of the subchord by the value of t given in Table I, and dividing the product by 10,000. As c is always less than 100, so t_1 is always less than t .

110. In equations 29, 32, and 33 it is customary to use the *nominal* values of the subchord, and this can produce no error in t_1 exceeding 0.005, when the degree of curve does not exceed 10° . In the case of a very sharp curve, formula 30 is preferable.

To Locate a Curve by Offsets from the Tangents

When the curve begins at a station:

111. Let *A*, Fig. 21, be the P.C. at a station. Then the next station *a* is located by the tangent offset *t*, taken from Table I, or calculated by equations 28, or 31. To calculate the distances and offsets for the following stations, *b*, *c*, etc., in the diagram, draw lines through the points *b*, *c*, etc., parallel to the tangent *AV*, intersecting the radius *AO* in *g'*, *g''*, etc., and draw the lines *by'*, *cy''*, etc., perpendicular to the tangent. Then,

$$Ay' = g'b = Ob \sin bOA$$

or

$$\left. \begin{aligned} Ay' &= R \sin 2D \\ Ay'' &= R \sin 3D \\ \text{etc.} &\quad \text{etc.} \end{aligned} \right\} \quad (34)$$

and

Also,

$$by' = g'A = Ob \text{ vers } bOA$$

or

$$\left. \begin{aligned} t' &= R \text{ vers } 2D \\ t'' &= R \text{ vers } 3D \\ \text{etc.} &\quad \text{etc.} \end{aligned} \right\} \quad (35)$$

and

But these calculations may be avoided, for, as twice *ag* equals the chord of two stations, so twice *bg'* equals the chord of four stations, and twice *cg''* the chord of six stations, and so on. So also, as *Ag* is the middle ordinate of two stations, *Ag'* is the middle ordinate of four, and *Ag''* the middle ordinate of six stations, etc. Hence, the rule:

The distance on the tangent from the tangent point to the perpendicular offset for the extremity of any arc is equal to one-half the long chord for twice that arc; and the offset from the tangent to the extremity of any arc is equal to the middle ordinate of twice that arc.

The long chords and middle ordinates may be taken from Tables IV and VI for 2, 4, 6, 8, etc., stations, when the P.C.

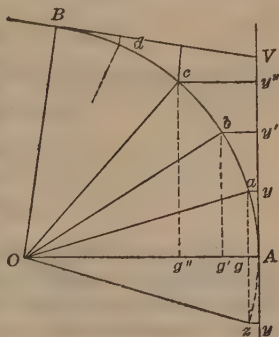


FIG. 21.

is at a station, or for 1, 3, 5, 7, etc., stations, when the P.C. is at +50, or half a station.

If the *offsets from the first tangent AV* prove inconveniently long, the second half of the curve may be located from the other tangent BV, beginning at the point of tangent B, and closing on a station located from the first tangent.

When the curve begins with a subchord:

112. If d = the angle at center, subtended by the first subchord, we have for the distances on the tangent (Fig. 22).

$$\left. \begin{aligned} Ay &= R \sin d \\ Ay' &= R \sin (d+D) \\ Ay'' &= R \sin (d+2D) \\ \text{etc.} \quad \text{etc.} \end{aligned} \right\} \quad (36)$$

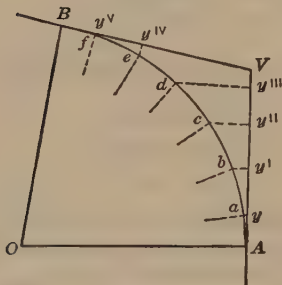


FIG. 22.

and, for the offsets (Fig. 22),

$$\left. \begin{aligned} t_1 &= R \text{ vers } d \\ t' &= R \text{ vers } (d+D) \\ t'' &= R \text{ vers } (d+2D) \\ \text{etc.} \quad \text{etc.} \end{aligned} \right\} \quad (37)$$

If the first subchord equals 50 ft (nominal), then $d = \frac{1}{2}D$, and the Tables IV and VI may be used as explained previously. These tables may be used in any case, by adopting a temporary tangent through any station, laying off the distances on this, and making the offsets from it.

When a curve is located by offsets, the chain should be carried around the curve, if possible, to prove that the stations are 100 ft apart.

To Locate a Curve by Middle Ordinates

When the curve begins and ends at a station:

113. In Fig. 23, let A be the P.C. at a station, and let a and z be the next stations on the curve either way from A . Then, since $zy = ax = t$, the chord za is parallel to the tangent AV , and $Ag = t$. Hence, having any two consecutive stations on the curve, as z and A , we may lay off the tangent offset t from A to g on the radius and find the next station a 100 ft

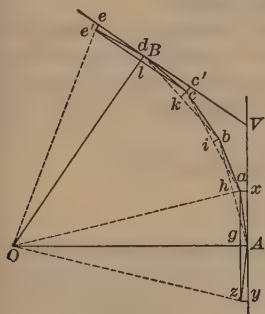


FIG. 23.

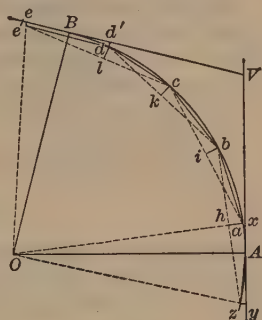


FIG. 24.

from A on the line zg produced. Then if $ah = t$ is laid off on the radius aO , a point on the line Ah produced and 100 ft from a will be the next station b .

When the end of the curve is reached, the tangent is found precisely as described in the method by chords produced, § 107.

In Fig. 23, since $\text{vers } AOa = gA/Oa = t/R$, we have

$$t = R \text{ vers } D \quad (38)$$

When the curve begins or ends with a subchord:

114. Let A , Fig. 24, be the P.C. and a and z the nearest stations. Then, $Aa = c$, the first subchord, and $aOA = d$, and, by analogy, we have from the last equation, if $ax = t_1$ and $zy = t_2$,

$$\left. \begin{aligned} t_1 &= R \text{ vers } d \\ t_2 &= R \text{ vers } (D-d) \end{aligned} \right\} \quad (39)$$

or equation 33 may be used if preferred.

Having found the two stations, a and z , on the curve, lay off from the forward station a , $ah = t$ on the radius, and so continue the curve as previously described.

When the end of the curve is reached, produce the curve to the next station beyond, and find the tangent by offsets as described in a previous method, § 108.

To Locate a Curve by Ordinates from a Long Chord

When the curve begins and ends at a station:

115. In Fig. 25 draw the long chord AB joining the tangent points, and from this draw ordinates to all the stations on the curve. We then require to know the several distances on the long chord Aa' , $a'b'$, $b'c'$, etc., and the length of ordinate at each point.

Let C = the long chord AB , then equation 18:

$$C = 2R \sin \frac{1}{2}\Delta$$

If a is the second station and i next to the last on the curve, join ai , and let the chord $ai = C'$. Then, since the arc $Aa = ik = D$, the angle at the center subtended by C' is $(\Delta - 2D)$.

$\therefore$

$$C' = 2R \sin \frac{1}{2}(\Delta - 2D)$$

Again, if we join b and h , the next stations, and let $bh = C''$:

$$C'' = 2R \sin \frac{1}{2}(\Delta - 4D)$$

and so on for other chords.

Since $Aa' = ki'$, $C = C' + 2Aa'$:

$\therefore$

$$Aa' = \frac{C - C'}{2}$$

Similarly,

$$a'b' = \frac{C' - C''}{2}$$

Thus, we continue to find the distances up to the middle of the curve, after which they repeat themselves in inverse order.

By Table IV:

Sta.		Diff.	$\frac{1}{2}$ Diff.
10	$C = 980.014$		
8	$C^I = 789.803$	190.211	$95.105 = Aa' = ki'$
6	$C^{II} = 595.744$	194.059	$97.030 = a'b' = i'h'$
4	$C^{III} = 398.782$	196.962	$98.481 = b'c' = h'g'$
2	$C^{IV} = 199.878$	198.904	$99.452 = c'd' = g'f'$
0	$C^V = 000.000$	199.878	$99.939 = d'e' = f'e'$

From Table VI:

Sta.		Diff.	
10	$M = 86.402$		
8	$M^I = 55.500$	30.902	$= a'a = i'i$
6	$M^{II} = 31.308$	55.094	$= b'b = h'h$
4	$M^{III} = 13.943$	72.459	$= c'c = g'g$
2	$M^{IV} = 3.490$	82.912	$= d'd = f'f$
0	$M^V = 0.000$	86.402	$= e'e$

117. When the long chord C subtends an **odd number of stations**, the middle ordinate will fall halfway between two stations and need not be laid off.

If the ordinates near the middle of the curve prove inconveniently long, we may subtract $M - M'$, $M' - M''$, etc., and so obtain in Fig. 25 $a'a$, $b'b$, $c'c$, etc. We then lay off Aa' , $a'a$, ab'' , $b'b$, bc'' , etc., turning a right angle at every point. The chain should be carried along the curve at the same time to make the stations 100 ft apart.

Example. It is required to locate a 10° curve of nine stations by offsets from the long chord.

By Table IV, similar to the foregoing, the long chords for 9, 7, 5, 3, 1, and 0 stations are, respectively, 811.314, 658.105, 484.900, 296.962, 100.000, and 0.0; the half differences are, respectively, 76.604, 86.603, 93.969, 98.481, and 50.000 which equal Aa' , $a'b'$, $b'c'$, $c'd'$, and $d'e'$.

Likewise, by Table VI, the middle ordinates for 9, 7, 5, 3, 1, and 0 stations are, respectively, 168.029, 103.750, 53.750, 19.548, 2.183, and 0.0; the differences are 64.279, 50.000, 34.202, 17.365, and 2.183, which equal $a'a$, $b'b$, $c'c$, etc.

118. The tables can be used equally well when the curve both begins and ends with a **half station** and also to locate half-station points throughout the curve, but in the latter

case the numbers are taken from *consecutive* columns of the tables instead of from *alternate* columns, as in the previous examples.

When the curve begins or ends with any subchord:

119. Let *A*, Fig. 26, be the P.C., $Aa = c$ the first subchord, and d the angle it subtends at the center. In the diagram

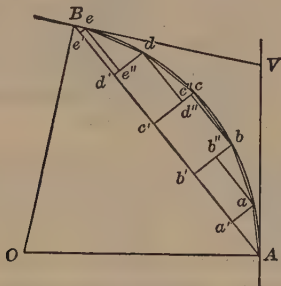


FIG. 26.

draw the long chord AB and the ordinates to each station, and through each station draw a line parallel to AB , and let $AOB = \Delta$.

Since the angle $VAB = \frac{1}{2}\Delta$ and $VAa = \frac{1}{2}d$, the angle $aAB = \frac{1}{2}(\Delta - d)$. The deflection angle from the subchord Aa produced to the chord ab is $\frac{1}{2}(d + D)$; the deflection angle between any two consecutive chords of 100 ft is $\frac{1}{2}(D + D) = D$. Therefore, the angle:

$$bab'' = \frac{1}{2}(\Delta - d) - \frac{1}{2}(d + D) = \frac{1}{2}(\Delta - 2d - D)$$

$$cbc'' = \frac{1}{2}(\Delta - 2d - D) - \frac{1}{2}(2D) = \frac{1}{2}(\Delta - 2d - 3D)$$

$$cdd'' = \frac{1}{2}(\Delta - 2d - 3D) - \frac{1}{2}(2D) = \frac{1}{2}(\Delta - 2d - 5D)$$

etc. etc. etc.

Solving the several right-angled triangles, we have (Fig. 26):

$$\left. \begin{aligned} Aa' &= c \cos \frac{1}{2}(\Delta - d) \\ ab'' &= 100 \cos \frac{1}{2}(\Delta - 2d - D) \\ bc'' &= 100 \cos \frac{1}{2}(\Delta - 2d - 3D) \\ dd'' &= 100 \cos \frac{1}{2}(\Delta - 2d - 5D) \end{aligned} \right\} \quad (40)$$

etc. etc.

and, also,

$$\left. \begin{aligned} a'a &= c \sin \frac{1}{2}(\Delta - d) \\ b''b &= 100 \sin \frac{1}{2}(\Delta - 2d - D) \\ c''c &= 100 \sin \frac{1}{2}(\Delta - 2d - 3D) \\ d''c &= 100 \sin \frac{1}{2}(\Delta - 2d - 5D) \\ &\text{etc.} \quad \text{etc.} \end{aligned} \right\} \quad (41)$$

When the middle point of the curve is passed, the minus quantities in the parentheses become greater than Δ , making the parentheses negative and, therefore, the sines negative and indicating that such values as are determined by them must be laid off *toward* the long chord AB .

By a proper summation of the quantities determined by equations 40 and 41 we obtain the distances Aa' , Ab' , Ac' , etc., and the ordinates $a'a$, $b'b$, $c'c$, etc., and the curve may be located accordingly. It is well to make all the necessary calculations before beginning to lay down the lines on the ground, thus avoiding confusion and mistakes.

Example. The P.C. of a $3^\circ 20'$ curve is fixed at +25 ft beyond a station, and the central angle is $16^\circ 24' = \Delta$. It is required to locate the curve by ordinates from the long chord.

We have $c = 100 - 25 = 75$ and $d = 2^\circ 30'$ and $D = 3^\circ 20'$. Hence, equations 40:

$Aa' = 75 \cos 6^\circ 57' = 74.449$	$74.449 = Aa'$
$ab'' = 100 \cos 4^\circ 02' = 99.752$	$174.201 = Ab'$
$bc'' = 100 \cos 0^\circ 42' = 99.993$	$274.194 = Ac'$
$d''d = 100 \cos (-2^\circ 38') = 99.894$	$374.088 = Ad'$
$e''e = 100 \cos (-5^\circ 58') = 99.458$	$473.546 = Ae'$
$e'B = 17 \cos (-7^\circ 55') = 16.838$	$490.384 = AB$

By equations 41:

$a'a = 75 \sin 6^\circ 57' = 9.075$	$9.075 = a'a$
$b''b = 100 \sin 4^\circ 02' = 7.034$	$16.109 = b'b$
$c''c = 100 \sin 0^\circ 42' = 1.222$	$17.331 = c'c$
$cd'' = 100 \sin (-2^\circ 38') = -4.594$	$12.737 = d'd$
$de'' = 100 \sin (-5^\circ 58') = -10.395$	$2.342 = e'e$
$ee' = 17 \sin (-7^\circ 55') = -2.341$	0.000

The same formulas can be used when the curve begins at a station by making $c = 100$ and $d = D$.

120. The methods of locating curves by linear measurements do not require the use of a transit, although one may be used to advantage for giving true lines, turning right angles, and the like. When a transit is not used, the alignments should be made across plumb lines suspended over the exact points previously marked on top of the stakes. A **right angle** may easily be obtained, without an instrument, by laying off on the ground the three sides of any of the right-angled triangles represented in the following table (or any multiples of them), always making the *base* coincide with the given line.

TABLE OF RIGHT-ANGLED TRIANGLES

Base	Hypotenuse	Perpendicular
4	5	3
12	13	5
20	29	21
24	25	7
40	41	9
60	61	11
84	85	13

OBSTACLES TO THE LOCATION OF CURVES

121. *To locate a curve when the P.I. is inaccessible* (Fig. 27). When the P.I. is inaccessible, a line is run (or traverse if necessary) connecting the two tangents. The length of the line and the deflection angles it makes with the tangents are measured. Δ is found by adding the deflection angles, and the distances from the ends of the line to the P.I. are computed by triangulation.

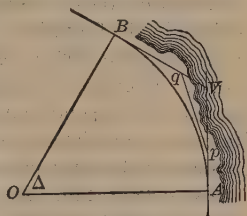


FIG. 27.

The steps used are the following:

1. Set p at a point from which a line can be run to the forward tangent.
2. Measure the plus of p .
3. Set q . Sighting from p , establish an intersection with the forward tangent by the usual method of setting a P.I.
4. Measure the angle at p with the same precision ordinarily used to measure Δ .

5. Measure pq . It is unnecessary to use the transit for alignment. The rear tapeman observing a range pole at q will give sufficiently accurate line.

6. Measure the angle at q with precision equal to that at p .

7. Compute $\Delta = p + q$.

8. Compute $pV = \frac{pq}{\sin \Delta} \sin q$.

9. Compute $Vq = \frac{pq}{\sin \Delta} \sin p$.

10. Compute plus P.I. = plus $p + pV$

11. Compute the curve data.

12. Compute q to $B = T - Vq$. (A minus sign indicates that the P.T. is nearer the P.I. than q .)

13. Set P.T. by measuring from q .

14. Set P.C.

15. Run curve.

16. Check at P.T. for line and distance.

122. *To locate a curve when the P.C. is inaccessible.* When the P.C. is inaccessible, a hub must be set on the curve at a known position as near the P.C. as possible. One of the three following positions is usually selected:

(a) Opposite a point of known plus on the back tangent.

(b) At a selected station on the curve.

(c) At a certain number of half stations beyond the P.C.

The set of steps necessary for each of these three procedures is given in the following. Included in these steps is a method of carrying the back tangent past the obstacle. The method chosen, of course, is independent of how the point p is to be located but depends on the type of obstacle encountered. However, sometimes the method of passing the obstacle is the deciding factor in choosing the procedure for establishing p .

Case a (Fig. 28). By setting p opposite a point of known plus on the back tangent:

1. Set e and g on line.

2. Measure the plus of e .

3. Set f . Measure ef and the angles e and f .

4. Measure angle g . Check $e + f + g = 180^\circ$.

5. Compute $eg = ef \sin f / \sin g$.

6. Compute plus of $g = \text{plus of } e + eg$.

7. Set P.I.

(On a right curve the vernier would be set clockwise.) This and similar settings are best computed by assuming certain imaginary operations. In this case, sight P.C. with vernier at zero and telescope reversed. This will orient the transit to the curve. Transit the telescope to the direct position. The line of sight will now be pointing along a line which makes an angle with the back tangent equal to the deflection of p while the vernier is still set at zero. With the telescope direct turn to p' . The angle turned will be counterclockwise and equal to $90^\circ - \text{defl. } p$. Since the vernier read zero to start, it will now read $90^\circ - \text{defl. } p$ counterclockwise. Accordingly, since this reading is obtained when the transit is oriented to the curve, pointing p' with this reading on the vernier will orient the transit.

The curve can now be staked out using the original list of deflection angles, beginning with the first station beyond p .

23. Check at P.T. for line and distance.

Case b (Fig. 29). By setting p at a selected station on the curve:

1. Set V' by offsets shown. Offset = h .
2. Measure the plus of V' .
3. Measure Δ at V' .
4. Compute $i = h \cot \Delta$.
5. Compute $VV' = h/\sin \Delta$.
6. Compute plus of P.I. = plus $V' + i$.
7. Compute T .
8. Compute plus of P.C.
9. Compute L .
10. Compute plus of P.T.
11. Compute deflection angles and subchord at P.T.
12. Set P.T. Measure $T + VV'$ from V' .
13. Note P.C. inaccessible.
14. Select the station p at which the curve is to be regained, and compute $Ap = \text{plus of } p - \text{plus P.C.}$
15. Compute $\alpha = Ap \times D/100$.
16. Compute $g'p = R \text{ vers } \alpha + h$.
17. Compute $Ag = R \sin \alpha$.
18. Compute plus of $g' = \text{plus of P.C.} + Ag$.
19. Set g' . Measure from nearest station on offset line.
20. Set p and p' at 90° from offset line.
21. Run curve (as in case a).

22. Check at P.T. for line and distance.

Case c (Fig. 30). By setting p at a certain number of half stations beyond the P.C.:

1. Note that P.C. is obviously inaccessible, and determine what offset will clear obstacle.

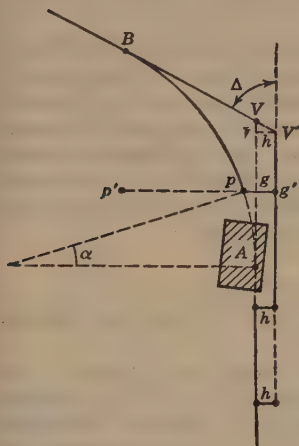


FIG. 29.

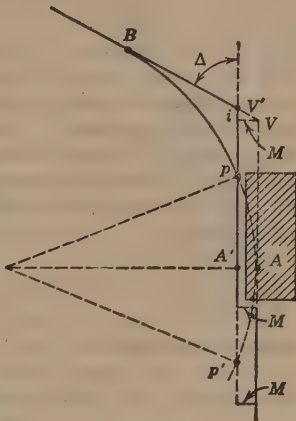


FIG. 30.

2. For the degree of curve given, using Table VI, find n , the number of stations having a middle ordinate M slightly larger than the required offset.

3. Set V' by offsets shown. Offset = M .

4. Measure the plus of V' .

5. Measure Δ at V' .

6. Compute $i = M \cot \Delta$.

7. Compute $VV' = M / \sin \Delta$.

8. Compute plus of P.I. = plus $V' - i$.

9. Compute T .

10. Compute plus of P.C.

11. Compute L .

12. Compute plus of P.T.

13. Compute $Ap = 50n$.

14. Compute plus of p = plus of P.C. + Ap .

15. Compute $A'p = \frac{1}{2}C$ for n stations (Table IV).

16. Compute plus of p on the offset line = plus of P.C. + $A'p$.

17. Compute the deflection angles and subchords. The deflection of p should equal $\frac{1}{2}n \times \frac{1}{2}D$.

18. Set P.T. Measure $T - VV'$ from V' .

19. Set p . Measure the plus from the station previous to p on the offset line.

20. Run the curve. Set up at p , and orient as follows. With the vernier set at the value of the deflection angle of p , but reading clockwise (counterclockwise for right curves), sight V' , telescope direct. To compute this value, the imaginary procedure is the following. Set the vernier at zero and sight P.C. telescope reversed. Turn to p' . The vernier will now read clockwise a value equal numerically to the deflection angle of p , since arc $Ap = \text{arc } Ap'$.

Continue the curve.

21. Check at P.T. for line and distance.

123. To locate a curve when both the vertex and point of curve are inaccessible (Fig. 31):

(a) From any point p on the tangent run a line pq' to the other tangent, and so determine pA as in § 121. Suppose the curve produced backward to p' on the perpendicular offset pp' .

Then,

$$\sin p'OA = \frac{pA}{R}$$

and

$$pp' = R \text{ vers } p'OA$$

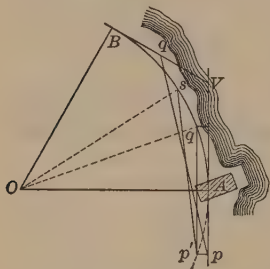


FIG. 31.

When the point p' has been located, a parallel chord $p'q$ may be laid off, giving a point q on the curve, since $p'q = 2 \times pA$. At q deflect from qp' an angle equal to $p'OA$ for a tangent to the curve at q .

(b) If any obstacle prevents using the chord $p'q$, any other chord as $p's$ may be used, by deflecting from $p'q$ the angle $qp's = \frac{1}{2}(qOs)$ and laying off its length,

$$p's = 2R \sin (p'OA + qp's)$$

At s a deflection from the chord sp' of $(p'OA + qp's)$ will give the tangent at s .

(c) If obstacles prevent the use of any chord, the methods described in § 125 may be resorted to.

124. To pass from a curve to the forward tangent when the point of tangent is inaccessible (Fig. 32):

(a) From any transit point p on the curve, near the end of the curve, run a chord parallel to the tangent. The middle

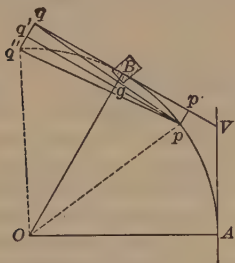


FIG. 32.

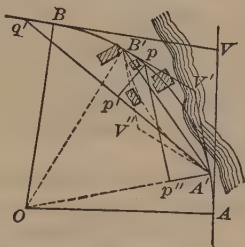


FIG. 33.

point g of the chord will be on the radius through the point of tangent B . At any convenient point beyond this, an offset equal to $pp' = R \text{ vers } pOB$ may be made to the tangent, and at some other point an equal offset will fix the direction of the tangent.

(b) Otherwise, if an unobstructed line pq can be found intersecting the tangent at a reasonable distance from B , measure the angle $q'pq = pqp'$, and lay off the distance,

$$pq = \frac{pp'}{\sin q'pq}$$

to fix the point q . Then,

$$Bq = p'q - p'B = pp' \cot q'pq - R \sin pOB$$

(c) Otherwise, assume an arc of any number of stations from p to q'' on the curve produced, and take the length of chord from Table IV. Lay off pq'' , and from q'' lay off $q''q = R$ vers $q''OB$, perpendicular to the tangent, to locate q . The angle $pq''q = 90^\circ - q'pq''$, and the distance $qB = R \sin q''OB$.

125. *To pass an obstacle on a curve (Fig. 33):*

(a) From any transit point A' on the curve take the direction of a long chord which will miss the obstacle, as $A'B'$.

The length of this chord is $2R \sin V'A'B'$, $V'A'$ being tangent to the curve at A' (see equation 18), and by measuring this distance the point B' on the curve is obtained. If the angle $V'A'B'$ is made equal to the deflection for an exact number of stations, the chord may be taken from Table IV.

(b) If the chord which will clear the obstacles would be too long for convenience, as $A'q'$, we may measure a part of it as $A'p'$ and, then, by an ordinate to some station, regain the curve at p . The distance on the curve from A' to p being assumed, the distances $A'p'$ and $p'p$ are calculated by the methods given in § 115 to § 119. If $p'p$ can be made a middle ordinate, the work will be much simplified. If more convenient the middle ordinate may first be laid off from A' to p'' , and the half-chord afterwards measured from p'' to locate p .

(c) Again, we may calculate the auxiliary tangent $A'V'$ for any assumed length of curve $A'B'$, and lay off the distance $A'V'$ and $V'B'$, deflecting at V' an angle equal to twice $V'A'B'$. But, if the point V' should prove inaccessible, we may conceive the auxiliary tangents to be revolved about the chord $A'B'$ as an axis, so that V' will fall at V'' , and the lines $A'V''$ and $V''B'$ may be laid out accordingly. If these in turn meet obstructions, we may run a curve from A' to B' of same radius as the given curve, but tangent to $A'V''$ and $V''B'$. This method appears less practical than any of the others.

(d) Again, the entire curve or any portion of it may be laid out by offsets from the tangents, or by ordinates from a long chord, as already explained.

(e) In case any distance on a curve must be measured by triangulation, as in crossing a stream, a long chord may be chosen, either end of which is accessible, and the triangulation is then performed with respect to this chord or a part of it, as on any other straight line.

SPECIAL PROBLEMS IN SIMPLE CURVES

Tangents Remaining in Same Position

126. *Given: a curve joining two tangents; to find the change required in the radius R and external distance E for an assumed change in the value of the tangent distance T (Fig. 34):*

Let

$$T = AV = VB; \quad T' = A'V = VB'; \quad R = AO; \quad R' = A'O'$$

$$E = VH \quad \text{and} \quad E' = VH'$$

Then

$$T - T' = AA' = \text{the given change}$$

By equation 21,

$$R = T \cot \frac{1}{2}\Delta$$

$$R' = T' \cot \frac{1}{2}\Delta$$

$$\therefore \qquad OG = R - R' = (T - T') \cot \frac{1}{2}\Delta \qquad (42)$$

By equation 22, similarly,

$$HH' = E - E' = (T - T') \tan \frac{1}{4}\Delta \qquad (43)$$

Equations 42 and 43 give the changes in R and E for any change in T . When T is increased, R and E will be increased also, and *vice versa*.

Example. A 4° curve joins two tangents, making an angle of $38^\circ = \Delta$, and it is necessary to shorten the last tangent distance 80 ft. What will be the change in the radius and in the external distance?

Ans.	$R - R'$	232.34
	R	1432.69
	$R' =$	1200.35 or about $4^\circ 46' = D'$

If the tangent distance had been increased 80 ft, we should add the above to R .

$$\therefore \qquad R' = 1665.03 \text{ or about } 3^\circ 26' = D'$$

Ans.	$E - E'$	13.387
------	----------	--------

127. *Given: a curve joining two tangents; to find the change required in the radius R and tangent distance T for any assumed change in the value of the external distance E (Fig. 34):*

We suppose HH' given, to find OG and AA' .

By equation 20,

$$E = R \operatorname{ex sec} \frac{1}{2}\Delta$$

$$E' = R' \operatorname{ex sec} \frac{1}{2}\Delta$$

$\therefore$

$$OG = R - R' = \frac{E - E'}{\operatorname{ex sec} \frac{1}{2}\Delta} \quad (44)$$

By equation 43,

$$AA' = T - T' = (E - E') \cot \frac{1}{4}\Delta \quad (45)$$

Example. A 4° curve joins two tangents, making an angle of $38^\circ = \Delta$, and it is necessary to bring the middle point of the curve 25 ft nearer the vertex V . What changes are required in the radius and point of curve?

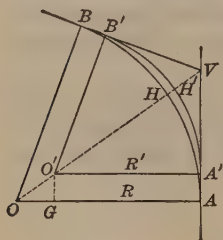


FIG. 34.

Ans. From equation 44, $R - R' = 433.87$; then $R' = 998.82$ and $D' = 5^\circ 44'$ about.

From equation 45, $T - T' = 149.39$.

But, if the point H , Fig. 34, were to be moved 25 ft further from the vertex V , then,

$$R' = 1866.56 \text{ or about } 3^\circ 04' = D'$$

and the P.C. will be moved 149.39 ft further from the vertex.

It is preferable to assume some radius from Table I near the value of R' found as above and from this calculate the value of T' by equation 17.

128. *Given: a curve joining two tangents; to find the change made in the tangent distance T and external distance E by any assumed change in the value of the radius R (Fig. 34):*

By equation 42,

$$AA' = T - T' = (R - R') \tan \frac{1}{2}\Delta \quad (46)$$

By equation 44,

$$HH' = E - E' = (R - R') \operatorname{ex sec} \frac{1}{2}\Delta \quad (47)$$

The changes calculated by equations 46 and 47 will be added to or subtracted from T and E , respectively, according as the radius is increased or diminished.

129. Since for a constant value of the central angle Δ the homologous parts of any two curves are proportional to each other, we may write at once:

$$\left. \begin{aligned} R' &= R \frac{T'}{T} = R \frac{E'}{E} = R \frac{C'}{C} = R \frac{M'}{M} \\ T' &= T \frac{R'}{R} = T \frac{E'}{E} = T \frac{C'}{C} = T \frac{M'}{M} \\ \text{etc.} &\quad \text{etc.} \quad \text{etc.} \end{aligned} \right\} \quad (48)$$

130. *Given: a curve joining two tangents; to change the position of the point of curve so that a curve of the same radius may end in a parallel tangent* (Fig. 35):

Let AB be the given curve; AV , VB the tangents; and $V'B'$ the parallel tangent. Then VV' is the distance from one vertex to the other; and, since there is no change in the form or dimensions of the curve, we may conceive it to be moved bodily, parallel to the line AV , until it touches the line $V'B'$, when every point of the curve will have moved a distance equal to VV' . Hence, $AA' = OO' = BB' = VV'$. Therefore, run a line from B parallel to AV , intersecting the new tangent in B' , measure BB' , and lay off the distance from A to find A' . In the figure the new tangent is taken outside the curve, and so A' falls beyond A , but, if the new tangent were taken inside the curve at $V''B''$, the new P.C. would fall back of A at some point A'' .

If the parallel tangent is defined by a perpendicular offset from B , as Bp , since the angle $BB'p = \Delta$:

$$AA' = BB' = \frac{Bp}{\sin \Delta} \quad (49)$$

The tangent distance T remains the same and is, from equation 17, $T = R \tan \frac{1}{2}\Delta$.

131. *Given: a curve joining two tangents; to find the radius of a curve that, from the same point of curve, will end in a parallel tangent* (Fig. 36):

Let AB be the given curve; AV , VB the tangents; and $V'B'$ the parallel tangent; and let $AO = R$ and $AO' = R'$.

Since the central angle Δ remains unchanged, the angle $\frac{1}{2}\Delta$ between the tangent and long chord remains unchanged; therefore, $V'AB' = VAB$, and the new point of tangent is on the long chord produced. The problem may be solved in several ways.

(a) If the perpendicular distance between the tangents is designated by p , the point V (=P.I.) will be moved a distance $VV' = p/\sin \Delta$, and the new tangent distance AV' will be

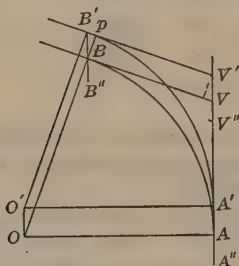


FIG. 35.

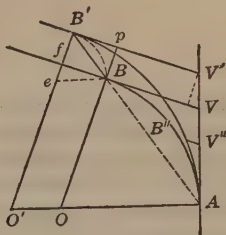


FIG. 36.

changed by the same amount, namely, $p/\sin \Delta$. The new radius R' may be found by equation 21, which is $R = T \cot \frac{1}{2}\Delta$. The degree of curve may be taken to the nearest minute with a consequent slight change in the value of p .

(b) Find on the ground the intersection of $V'B'$ with AB produced and measure BB' . In the diagram draw Be parallel to AO ; then $BeB' = \Delta$, and, by equation 18,

$$BB' = 2Be \sin \frac{1}{2}\Delta$$

but

$$Be = OO' = R' - R$$

$\therefore$

$$R' = R \pm \frac{BB'}{2 \sin \frac{1}{2}\Delta} \quad (50)$$

Use the lower sign when the parallel tangent cuts the chord AB at some point B'' , since R' will evidently be less than R .

If the parallel tangent is defined by a perpendicular offset, as $Bp = B'f$; since $BeB' = \Delta$:

$$Bp = Be \text{ vers } \Delta = (R' - R) \text{ vers } \Delta$$

$$R' = R \pm \frac{Bp}{\text{vers } \Delta} \quad (51)$$

Add or subtract as previously explained.

If the long chord $C = AB$ is known, then the new long chord $C' = AB'$ or $AB'' = C \pm BB'$, and, by equation 48,

$$R' = R \frac{C \pm BB'}{C} \quad (52)$$

132. *Given: a curve joining two tangents; to change the radius and also the point of curve, so that the new curve may end in a parallel tangent directly opposite the given point of tangent (Fig. 37):*

Let AB be the given curve; AV , VB the tangents; $V'B'$ the parallel tangent; and B' the given tangent point on the radius OB produced.

(a) If p denotes the perpendicular distance between the tangents, the point V (=P.I.) will, as in § 131, be moved a distance $VV' = p/\sin \Delta$, and the new tangent distance will be changed by $p/\tan \Delta$. Then, having Δ and the new T , find the new radius (R') by equation 21, $R = T \cot \frac{1}{2}\Delta$. If the degree of curve is taken to the nearest minute, the necessary slight change should be made in the value of p .

(b) In the diagram, produce the tangent AV and the radius OB to intersect at K . Then:

$$BK = R \text{ ex sec } \Delta$$

$$B'K = R' \text{ ex sec } \Delta$$

Subtracting, we have

$$BB' = (R - R') \text{ ex sec } \Delta$$

$\therefore$

$$R - R' = \frac{BB'}{\text{ex sec } \Delta} \quad (53)$$

from which R' is easily determined, as in §§ 126 and 127.

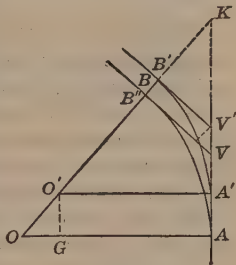


FIG. 37.

To find the change AA' of the P.C., in the diagram, draw $O'G$ parallel to $A'A$; then:

$$O'G = OG \tan \Delta$$

or

$$AA' = (R - R') \tan \Delta \quad (54)$$

(c) By substituting the value of $(R - R')$ from equation 53 and observing Table XLII, 42, we have

$$AA' = BB' \times \cot \frac{1}{2}\Delta \quad (55)$$

Observe that equations 53, 54, and 55 may be derived directly from equations 44, 46, and 45, respectively, by writing Δ for $\frac{1}{2}\Delta$.

133. *Given: a curve joining two tangents; to find the new tangent points after each tangent has been moved parallel to itself any distance in either direction (Fig. 38):*

Let A and B be the given tangent points, and A' and B' the new tangent points required. Let the known perpendicular distances $Aq = a$ and $Bp = b$. We then require the unknown parallel distances $qA' = x$ and $pB' = y$.

Since the form and dimensions of the curve remain unchanged, we may conceive the curve to be moved bodily into its new position on lines parallel and equal to the line VV' joining the vertices. Then, $AA' = OO' = BB' = VV'$.

In the diagram draw VK parallel and equal to $Bp = b$ and $V'H$ parallel and equal to $Aq = a$. Then, $VH = qA' = x$, and $V'K = B'p = y$. Since $VG V' = \Delta$, we have

$$VG = \frac{b}{\sin \Delta} \quad \text{and} \quad GH = \frac{a}{\tan \Delta}$$

and, since

$$VH = VG - GH = x$$

$$\left. \begin{aligned} x &= \frac{b}{\sin \Delta} - \frac{a}{\tan \Delta} \\ y &= \frac{b}{\tan \Delta} - \frac{a}{\sin \Delta} \end{aligned} \right\} \quad (56)$$

When the new tangents are outside the given curve, the offsets a and b are considered positive; if either new tangent were inside the given curve, its offset would be considered

negative. In solving equations 56, if x and y are found to be positive, they are to be laid off *forward* from q and p , as in Fig. 38; if either is found to be negative, it is to be laid off in the opposite direction.

Example. A certain curve has a central angle of $50^\circ = \Delta$, and it is proposed to move the first tangent *in* 20 ft and

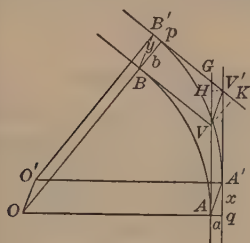


FIG. 38.

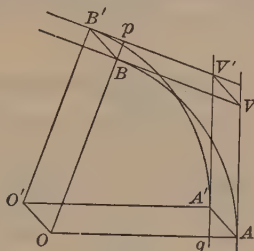


FIG. 39.

the second tangent *out* 12 ft. Required, the distances on the tangents from the old tangent points to the new (Fig. 39).

Here, $a = -20$ and $b = +12$

$+b$	12	1.079181	$-a$	20	1.301030
Δ	50°	$\log \sin$	Δ	50°	$\log \tan$
		9.884254			0.076186
	15.665	1.194927		16.782	1.224844

$\therefore$

$$x = 15.665 - (-16.782) = +32.447$$

$+b$	12	1.079181	$-a$	20	1.301030
Δ	50°	$\log \tan$	Δ	50°	$\log \sin$
		0.076186			9.884254
	10.069	1.002995		26.108	1.416776

$\therefore$

$$y = 10.069 - (-26.108) = +36.177$$

For $+a$ and $-b$,

$$\begin{cases} x = -32.450 \\ y = -36.177 \end{cases}$$

For $+a$ and $+b$,

$$\begin{cases} x = -1.120 \\ y = -16.039 \end{cases}$$

For $-a$ and $-b$,

$$\begin{cases} x = +1.120 \\ y = +15.939 \end{cases}$$

If we have a and x given to find b and y : Solving equations 56 for b and y , we obtain

$$\left. \begin{aligned} b &= x \sin \Delta + a \cos \Delta \\ y &= x \cos \Delta - a \sin \Delta \end{aligned} \right\} \quad (57)$$

in which the algebraic signs of the quantities must be observed as previously.

Change in Direction of Forward Tangent

134. *Given: a curve joining two tangents; to find a new radius and new position of the point of curve, such that the curve may end at the same point as before, but with a given change in the direction of the forward tangent (Fig. 40):*

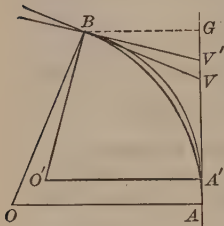


FIG. 40.

Let AB be the given curve; AV , VB the given tangents; $V'B$ the new tangent; and VBV' the given change in direction. Let $\Delta' = \Delta + VBV'$.

In the diagram draw BG perpendicular to AV produced; then,

$$\begin{aligned} BG &= R \text{ vers } \Delta \\ &= R' \text{ vers } \Delta' \end{aligned}$$

Hence,

$$R' = R \frac{\text{vers } \Delta}{\text{vers } \Delta'} \quad (58)$$

and

$$AA' = AG - A'G = R \sin \Delta - R' \sin \Delta' \quad (59)$$

In the figure the change in direction of tangent makes Δ' greater than Δ ; therefore, V' falls beyond V , and A' beyond A ; but, if the change made Δ' less than Δ , then V' and A' would fall behind V and A , respectively, and R' would be greater than R .

The same formulas apply to the converse problem in which B is taken as the point of curve and A and A' as points of tangent.

135. *Given: a curve joining two tangents; to find the change in the point of curve when the forward tangent takes a new direction from the vertex, V (Fig. 41):*

By equation 17,

$$VA = R \tan \frac{1}{2}\Delta, \quad VA' = R \tan \frac{1}{2}\Delta'$$

$\therefore$

$$AA' = R (\tan \frac{1}{2}\Delta - \tan \frac{1}{2}\Delta') \quad (60)$$

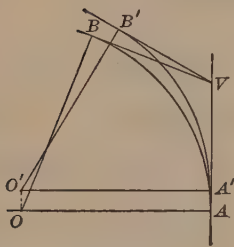


FIG. 41.

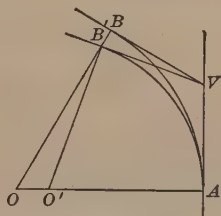


FIG. 42.

136. *Given: a curve joining two tangents; to find the new radius R' , when the forward tangent takes a new direction from the vertex, V (Fig. 42):*

By equations 17 and 21,

$$VA = R \tan \frac{1}{2}\Delta, \quad R' = VA \cot \frac{1}{2}\Delta'$$

$\therefore$

$$R' = R \tan \frac{1}{2}\Delta \cot \frac{1}{2}\Delta' \quad (61)$$

137. *Given: a curve joining two tangents, and a given change in the direction of the forward tangent from the vertex; to find*

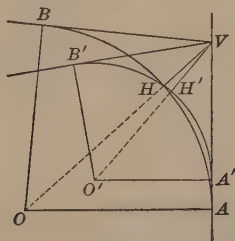


FIG. 43.

the radius and point of curve of a curve that shall pass at the same distance VH from the vertex (Fig. 43):

Let AB be the given curve, BVB' the given change in direction of tangent, and $VH' = VH$. Let $\Delta' = \Delta + BVB'$, then, equation 20,

$$VH = R \text{ ex sec } \frac{1}{2}\Delta = VH' = R' \text{ ex sec } \frac{1}{2}\Delta'$$

$\therefore$

$$R' = R \frac{\text{ex sec } \frac{1}{2}\Delta}{\text{ex sec } \frac{1}{2}\Delta'} \quad (62)$$

By equation 24,

$$VA = VH \cot \frac{1}{4}\Delta, \quad VA' = VH' \cot \frac{1}{4}\Delta'$$

$\therefore$

$$AA' = VH (\cot \frac{1}{4}\Delta - \cot \frac{1}{4}\Delta') \quad (63)$$

But, in case $\Delta' = \Delta - BVB'$, AA' becomes negative and must be laid off backward from A .

Example. Given a 2° curve, $\Delta = 80^\circ$ and $BVB' = -10^\circ$
 $\therefore \Delta' = 70^\circ$.

Ans. From equation 61, $D' = 1^\circ 27'$ nearly, and from equation 62, $AA' = -371.08$, which means that A' must be laid off backward from A .

To Pass a Curve Through a Given Point

138. *Given: two indefinite tangents, a point situated between them, and the angle Δ ; to find the radius R and tangent distance*

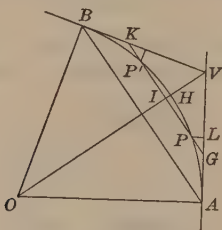


FIG. 44.

T of a curve joining the tangents which shall pass through the given point (Fig. 44):

The position of P must be tied to one of the tangents. Assume that its plus (the plus of L) and offset PL have been measured. Make the following computation.

$$PG = \frac{PL}{\sin \frac{1}{2}\Delta}$$

$$LG = PL \cot \frac{1}{2}\Delta$$

$$VL = \text{plus of P.I.} - \text{plus of } L$$

$$VG = VL + LG$$

$$GI = VG \cos \frac{1}{2}\Delta$$

$$GP' = 2GI - PG$$

$$GA = \sqrt{GP' \times PG} \quad (\text{Geom. Table XLI, 24}) \quad (64)$$

$$T = VG + GA$$

$$R = T \cot \frac{1}{2}\Delta$$

139. *Given: a curve AP and the radial offset PP'; to find the radius of a curve which shall pass through the point P', starting from the same point of curve A (Fig. 45):*

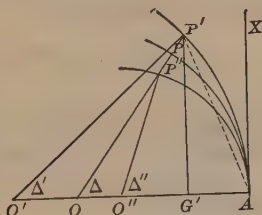


FIG. 45.

(a) Let $b = PP'$, and in the diagram draw $P'G'$ parallel to the common tangent AX , and join AP' . Then,

$$P'G' = (R \pm b) \sin \Delta$$

$$G'A = R - (R \pm b) \cos \Delta$$

$\therefore$

$$\tan \frac{1}{2}\Delta' = \tan G'P'A = \frac{G'A}{P'G'} = \frac{R}{(R \pm b) \sin \Delta} - \cot \Delta \quad (65)$$

$$R' = O'P' = \frac{P'G'}{\sin \Delta'} = \frac{(R \pm b) \sin \Delta}{\sin \Delta'} \quad (66)$$

When the offset is *outward*, use $R+b$; when it is *inward*, use $R-b$.

Example 1. Given: a 3° curve of 16 stations and a radial offset of 205 ft inward from the P.T.; to find the radius of the curve passing through the extremity of the offset.

Ans. $\Delta = 48^\circ$, and $b = 205$. From equation 65, $\Delta' = 62^\circ 31'$ and, from equation 66 and Table I, $D' = \text{about } 4^\circ 01'$.

If the same offset were made *outside* the curve, we should find $R' \log 3.438350$, or about a $2^\circ 05'$ curve.

This solution is inconveniently long for ordinary field practice. When the offset is small compared with the length of curve, we may use the following:

(b) **Approximate Rule:** Divide twice the offset b by the length of curve, look for the quotient in the table of natural sines, and take out the corresponding angle, which multiply by 100, and divide by the length of curve. The *quotient* is the *correction* for the given degree of curve, to be *subtracted* when the offset is made *outward* and *added* when the offset is made *inward*.

This rule is expressed by the formula:

$$D' = D \mp \frac{100}{L} \sin^{-1} \frac{2b}{L} \quad (67)$$

For the necessary change in Δ is equal to twice the angle PAP' which is expressed by $\sin^{-1} [2b/L]$, and to reduce this to degree of curve we multiply by $100/L$, as in equation 9. Whence, equation 67 results.

Taking the same example, we have

$$\frac{2b}{L} = \sin 14^\circ 51'$$

and

$$\text{Correction} = 14^\circ 51' \times \frac{100}{1600} = \mp 0^\circ 56'$$

Hence,

$$D' = 3^\circ 56' \quad \text{or} \quad D' = 2^\circ 04'$$

(c) *Given:* the degree of a curve passing through a certain point and the distance from the P.C. to the point; to find the radius of a new curve to pass a certain distance to the right or left of the point, starting from the same point of curve A (Figs. 46 and 45):

In Fig. 46 draw OG and PN perpendicular, respectively, to AP and AN . Then the triangles ANP and OAG are similar, and

$PN:AP::AG:OA$ from which, since $OA = R$, and $AG = \frac{1}{2}AP = \frac{1}{2}C$, $PN = C^2/2R$.

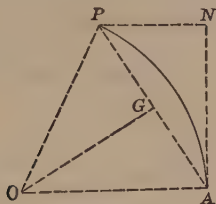


FIG. 46.

Since $R = 5730/D$ (approx.) and $C = 100n$ (approx.), where n = the number of chords in the curve,

$$PN = t = \frac{10000n^2D}{2(5730)} = 0.873n^2D$$

or

$$t = \frac{7}{8}n^2D \quad (\text{approx.}) \quad (68)$$

If in Fig. 45 the degree of the first curve is D' and that of the second is D'' , the tangent offsets between the two curves is approximately

$$t_{\text{diff}} = \frac{7}{8}n^2(D' \pm D'')$$

or

$$D' \pm D'' = \frac{t_{\text{diff}}}{\frac{7}{8}n^2} \quad (69)$$

Example. Taking the same data as that given in b , $D' = 3^\circ$, $n = 16$, and $t = 205$, we get

$$D' \pm D'' = 0^\circ 55' \quad \text{and} \quad D'' = 2^\circ 05' \quad \text{or} \quad 3^\circ 55'$$

depending on whether the offset is toward or away from the center.

These values are nearly the same as those in the approximate solution in b where D'' was $2^\circ 04'$ or $3^\circ 56'$. Of course, this was to be expected since the approximations in the derivation of equations 67 and 68 are entirely similar.

Equations 68 and 69 will be found most useful in problems of field location.

140. *Given: two tangents intersecting at V, a point P located by an angle and a distance from V, to find the radius of a curve joining the two tangents and passing through the point P (Fig. 47):*

We have angle AVP and distance $VP = d$; let $OA = OB = R$.

Now the angle $OVA = \frac{1}{2}(180^\circ - \Delta)$ and $OVP = \frac{1}{2}(180^\circ - \Delta) - AVP = 90^\circ - (\frac{1}{2}\Delta + AVP)$.

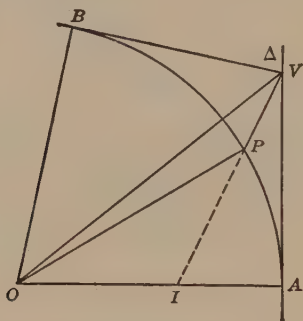


FIG. 47.

Again, $OA/OV = \cos \frac{1}{2}\Delta$ or $OV = R/\cos \frac{1}{2}\Delta$, and, in the triangle OPV ,

$$\frac{\sin OPV}{\sin OVP} = \frac{OV}{OP}$$

whence,

$$\sin OPV = \frac{\sin OVP}{\cos \frac{1}{2}\Delta}$$

Then

$$\text{Angle } VOP = 180^\circ - (OPV + OVP)$$

Again, using the sine formula on the triangle OPV , we have

$$OP = R = \frac{\sin OVP}{\sin VOP} d$$

Various cases may arise as follows:

(a) When $AVP = AVO$, the equation becomes the same

as that in § 97, which is

$$R = \frac{VP}{\text{ex sec } \frac{1}{2}\Delta} = \frac{E}{\text{ex sec } \frac{1}{2}\Delta} \quad (23)$$

(b) When $AVP = 90^\circ$,

$$VP = R \text{ vers } POA$$

or

$$R = \frac{VP}{\text{vers } POA}$$

and

$$\sin POA = \frac{T}{R}$$

Modification. In right-of-way work and in the location of highways the principles of this problem arise. Suppose a straight line (property or street line, for example) intersects the circular arc of a highway or the right-of-way line of a railroad, and it is desired to find the point of intersection of the two. The problem may be solved in two ways.

(c) By “string intersection.” The curve is located on the ground as also the direction of the line VI . Place two stakes on the line VI (one each side of P), and find by trial where the curve cuts a string joining the two stakes.

(d) By computation. In the triangle VPO the angle AVP is given, and $OP = R$.

Now,

$$AVO = 90^\circ - AOV = 90^\circ - \frac{1}{2}\Delta$$

$$PVO = AVO - AVP = 90^\circ - \frac{1}{2}\Delta - AVP$$

$$OV = R \sec \frac{1}{2}\Delta$$

and

$$\sin VPO = \sin PVO \left(\frac{OV}{R} \right) = \frac{\sin PVO}{\cos \frac{1}{2}\Delta}$$

Then,

$$VOP = 180^\circ - (VPO + PVO)$$

and

$$PV = d = R \frac{\sin VOP}{\sin PVO}$$

This gives the distance of P from V .

Miscellaneous Problems

141. *Given: a curve and a distant point; to find a tangent that shall pass through the point (Fig. 48):*

The curve *adg* is given, and the point *P* is visible but distance unknown, to find the point of tangent *B*.

(a) **By trial.** Set up at a point on the curve which is thought to be near where the final point will come. Establish a tangent to the curve at this point, and measure the angle

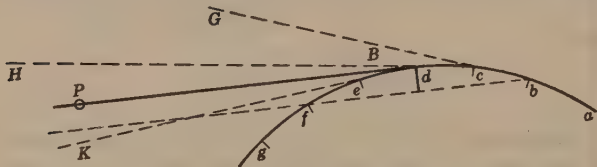


FIG. 48.

between this tangent and the point *P*. Move the transit forward or backward by a distance equal to that expressed

by the equation, $L = 100 \frac{\text{angular change in direction}}{\text{degree of curve}}$. Lay off

this distance, and check the work. If the established curve is of regular curvature and there has been no mistake in the work, the tangent to the curve at the new setup will pass through the point *P*.

(b) **By tape alone.** Any chord, as *bf*, parallel to the required tangent, if produced will pass the point *P* at a perpendicular distance equal to the middle ordinate of that chord. Ranging across every two consecutive stakes on the curve we at first find the range falling outside the required tangent, as *bcG*, *cdH*, etc.; but, finally, the range falls inside, as *deK*. We then know that the required point is between *c* and *e*. If the range *ce* falls inside the point *P*, a perpendicular distance equal to the middle ordinate of *ce*, the tangent point is at *d*. If the perpendicular distance is greater than this, the point *B* is between *c* and *d*. If it is less, or if the range *ce* falls outside *P*, the point *B* is between *d* and *e*. The middle ordinate for *ce* (200 ft) equals the tangent offset for 100 ft, given in Table I, and it is generally so small that it can be estimated at *P* without going to lay it off.

To find the exact point B , when it falls between d and e , find by trial a point x (not shown) such that the chord xe passes inside the point P by a distance equal to the middle ordinate of the chord xe . The point B is at the middle point of the arc ex . When the point falls between d and c , proceed in a similar way.

The middle ordinate of any chord ex is less than M for 200 ft, and greater than m for 100 ft. If necessary, its exact value m' can be found by

$$m' = \frac{m \times \overline{ex^2}}{10,000} \quad (70)$$

and this equation is nearly true when ex is as great as 300 or 400 ft. That is, middle ordinates on the same curve are to each other as the squares of their chords *very nearly*.

By this method the point B is found without the use of the transit, so that the plug can be driven at B before the transit is brought up from the rear. It is therefore preferable to the following solution.

(c) **By transit** (Fig. 49). From any two points a and c of the curve measure the angles to the point P , so that with the chord ac as a base, and the measured angles, we may find cP by the formula:

$$cP = ac \frac{\sin caP}{\sin cPa}$$

Knowing the angle c that cP makes with a tangent at c , we find the length of the chord cd by $cd = 2R \sin c$.

By Geom. Table XLI, 24,

$$PB = Pe = \sqrt{cP \times dP}$$

whence we know ce . Opposite e , or on the arc eB described with the radius Pe , we find B .

142. Given: two curves exterior to each other; to find the tangent points of a line tangent to both and its length between tangent points (Fig. 50):

Case I. When the curves are reverse to each other:

(a) **By trial in the field.** If the curves actually exist on the ground, run out a trial line in a position judged as nearly right as possible. Note the distance to and the amount the trial tangent fails to hit the second curve. The error divided by

the length of the tangent will give the natural tangent of the angle by which the transit station on the first curve must be changed.

(b) **By traverse.** Run a traverse from one curve to the other; this locates the positions of the centers of the curves. For instance, in Fig. 50 set up the transit at C , and find the



FIG. 49.

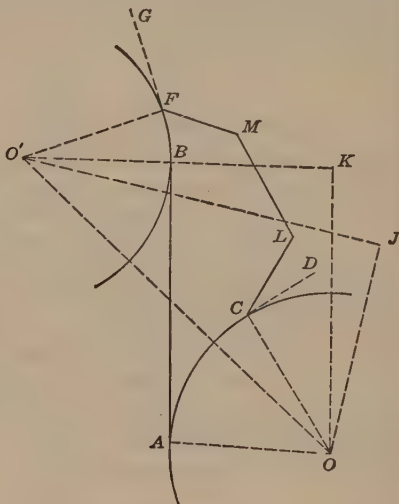


FIG. 50.

direction and bearing of the tangent CD to the curve. The angle $DCO = 90^\circ$ will locate the directions of the center O and the radius $CO = r_1$. Run a traverse from C to a point F on the second curve. Establish the tangent FG to the second curve at F and the angle between FG and the center of the second curve O' .

The latitudes and departures of the courses $OCFO'$ are then computed. If OJ = the sum of the latitudes and $O'J$ the sum of the departures,

$$\tan O'OJ = \frac{O'J}{OJ}$$

and

$$OO' = \sqrt{O'J^2 + OJ^2}$$

In the figure, AB is the required tangent and OA must be perpendicular to and OK parallel to AB .

Solve the triangle $OO'K$ where $O'K = r_1 + r_2$, and OO' is known. Then,

$$\sin KOO' = \frac{r_1 + r_2}{OO'}$$

and $OK = \text{length of required tangent} = OO' \cos KOO'$.

The angle COA will locate the tangent point A at which a setup may be made and a tangent to the curve established, and this line projected should strike the second curve at B .

Find COA as follows: Angles JOA and JOC are known since the bearings of OA and OC either are known or can be found.

$$AOC = JOA - JOC$$

Case II. *When the curves turn in the same direction:*

Solutions a and b are entirely similar to those in Case I. In b the side of the triangle $O'K$ will be the difference of the radii instead of their sum. Otherwise, the procedure is the same.

Note.—The previous problem has probably caused more discussion in the *Engineering News* and the *Engineering News-Record* than any other single curve problem. The treatment given is believed by the author to be the best solution.

143. *Given: two curves O and O' , reverse to each other, joined by a tangent BA' , and terminating in another tangent, $B'F$; to change the position of the Point of Tangent B of the first curve, so that the second curve may terminate in a given parallel tangent $B''F'$ (Fig. 51):*

Let X be the required new position of B
 O'' be the corresponding position of O'
 $\Delta' = A'O'B'$ and $\Delta'' = A''O''B''$

Since the radii and the connecting tangent are unchanged in length, and all rotate together about O as a center, O'' will be on a circle passing through O' , described with a radius OO' and the required angle $BOX = O'OO''$.

In the diagram, produce $O'A'$, draw the perpendicular OG , and let $\alpha = \text{the angle } OO'G$. Also, draw OK parallel and

which gives the distance, measured on the parallel tangent, between the old tangent point and the new.

This problem occurs in practice when both the connecting tangent and the radius of the last curve are at their *minimum limit* and the parallel tangent is *inside* the old one, as in the figure. Should the new tangent be *outside*, the same formulas apply, with only the sign of $B'F'$ being changed in equation 73. But in this last case it is usually preferable to employ problem § 130 or § 131.

Example. A $1^\circ 40'$ curve is followed by a tangent of 200 ft, and that by a 4° curve of 10 stations ending in a tangent; and the offset to the given parallel tangent is 80 ft on the inside. Required, the position of the new tangent points X and B'' .

Here $R = 3437.87$, $R' = 1432.69$, $BA' = 200$, $B'F' = 80$.

By equation 71, $R + R'$	4870.56	log 3.687579
BA'	200.	log 2.301030

$\therefore \alpha$	$2^\circ 21'$	log cot 1.386549
---------------------	---------------	------------------

By equation 72, α	$2^\circ 21'$	log cos 9.999635
--------------------------	---------------	------------------

$\therefore$	OO'	3.687944
--------------	-------	----------

By equation 73, $B'F'$	80	1.903090
------------------------	----	----------

	0.01641	8.215146
--	---------	----------

$\alpha + \Delta'$	$42^\circ 21'$	cos 0.73904
--------------------	----------------	-------------

$\alpha + \Delta''$	$40^\circ 56'$	cos 0.75545
---------------------	----------------	-------------

By equation 74, BOX	$1^\circ 25'$	$\therefore BX = 85$ ft. <i>Ans.</i>
-----------------------	---------------	--------------------------------------

By equation 75, $PO'O''$	$41^\circ 38' 30''$	cot 1.12468
		$\times 80 = 89.97$
		$= F'B''$

144. The traverse method. Many of the special problems of simple curves may be solved by what is called the traverse method and often termed the cases of supplying missing data. Among these cases may be mentioned the passing of obstacles and the location of a curve where certain points are inaccessible. The reader is referred to books on surveying for detailed solutions, and also to Chapter XXI and § 420 of this book.

CHAPTER VI

COMPOUND CURVES

THEORY

145. A compound curve consists of two or more consecutive circular arcs of different radii, having their *centers* on the *same side* of the curve; but any two consecutive arcs must have a *common tangent* at their meeting point, or their *radii* at this point must coincide in direction. The meeting point is called the Point of Compound Curve, or P.C.C. *Compound curves are employed to bring the line of the road upon more favorable ground than could be done by the use of any simple curve.*

In mountainous country it is often necessary to have compound curves of several arcs. In such cases a field location is usually resorted to. The cases here treated are combinations of either two or three simple curves. The latter is called a three-centered compound curve.

146. In a compound curve of two arcs, there are seven quantities: the two radii (or two degrees of curve), the two central angles, the two tangent distances, and the total change of direction of the tangents. In the adopted notation R_2 is always the longer and R_1 is always the shorter radius; T_2 is the longer and T_1 the shorter tangent distance. However, Δ_2 and Δ_1 do not have this relation. Δ_2 is the central angle for arc with radius R_2 and Δ_1 that for radius R_1 regardless of the order in the line of track. The total change in direction $\Delta = \Delta_1 + \Delta_2$. Any four of the seven quantities may be given or assumed within certain limits. In this discussion these given or assumed sets of quantities will be treated as cases.

In practice, Δ is always known or immediately available from the equation $\Delta = \Delta_1 + \Delta_2$. Of the six remaining quantities, three must be given or assumed for a solution. Stated

Solve the triangle VGH for VG and VH , knowing the angles at G and H and the distance GH .

Finally,

$$AV = T_2 = R_2 \tan \frac{1}{2}\Delta_2 + VG$$

and

$$BV = T_1 = R_1 \tan \frac{1}{2}\Delta_1 + VH$$

148. Cases I, II, III, IV, and V may be solved by use of the general equations which will now be derived.

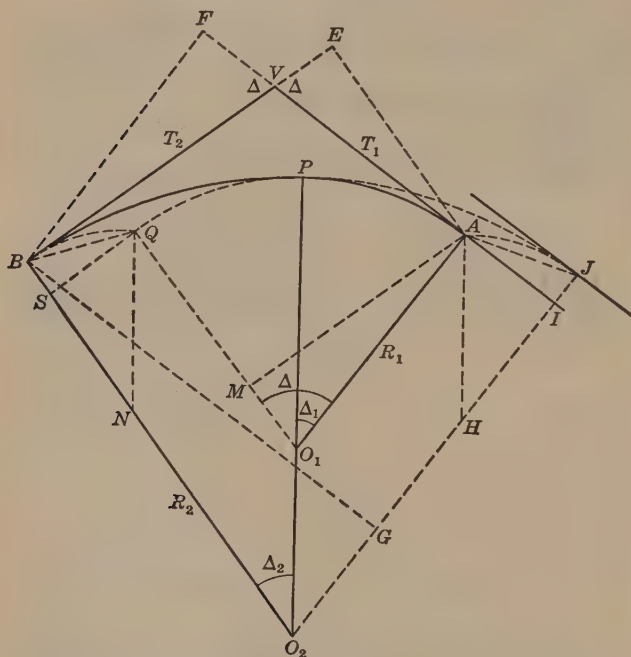


FIG. 53.

149. General equations. In Fig. 53, AP and PB are the two arcs of a compound curve. The radii O_1A and O_2P are designated by R_1 and R_2 and the central angles are Δ_1 and Δ_2 . The tangents AV and BV are denoted by T_1 and T_2 .

Construction. Produce the arc AP to Q so that the angle $AO_1Q = \Delta$; likewise, produce arc BP to J so that the angle $PO_2J = \Delta_1$. Draw AM and QS perpendicular to O_1Q and O_2B , respectively. Draw QN and AH parallel to PO_2 , BG perpendicular to O_2J , BF and AE perpendicular to AV and BV produced.

Draw the chord QB , and from N as a center and radius NQ ($= R_2 - R_1$) describe an arc. Likewise, draw chord AJ and from H as a center with radius HA ($= R_2 - R_1$) describe the arc AJ .

From the figure,

$$AE = MQ + SB$$

or

$$T_1 \sin \Delta = R_1 \text{ vers } \Delta + (R_2 - R_1) \text{ vers } \Delta_2 \quad (76)$$

Similarly,

$$BF = GJ - IJ$$

or

$$T_2 \sin \Delta = R_2 \text{ vers } \Delta - (R_2 - R_1) \text{ vers } \Delta_1 \quad (77)$$

Also,

$$\tan JAI = \tan \frac{1}{2} \Delta_1 = \frac{JI}{AI}$$

$$JI = GJ - GI = R_2 \text{ vers } \Delta - T_2 \sin \Delta$$

and

$$AI = BG - FV - VA = R_2 \sin \Delta - T_2 \cos \Delta - T_1$$

$$\tan \frac{1}{2} \Delta_1 = \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{R_2 \sin \Delta - T_2 \cos \Delta - T_1} \quad (78)$$

Likewise,

$$\tan BQS = \tan \frac{1}{2} \Delta_2 = \frac{SB}{SQ}$$

$$SB = AE - MQ = T_1 \sin \Delta - R_1 \text{ vers } \Delta$$

and

$$SQ = BV + VE - MA = T_2 + T_1 \cos \Delta - R_1 \sin \Delta$$

$\therefore$

$$\tan \frac{1}{2} \Delta_2 = \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{T_2 + T_1 \cos \Delta - R_1 \sin \Delta} \quad (79)$$

150. Case I. *Given or assumed:* R_1 , R_2 , Δ_1 , Δ_2 ; *required* Δ , T_1 , and T_2 .

$$\Delta = \Delta_1 + \Delta_2$$

Solving general equations 76 and 77 we find,

$$T_1 = \frac{R_1 \text{ vers } \Delta + (R_2 - R_1) \text{ vers } \Delta_2}{\sin \Delta} \quad (76A)$$

and

$$T_2 = \frac{R_2 \text{ vers } \Delta - (R_2 - R_1) \text{ vers } \Delta_1}{\sin \Delta} \quad (77A)$$

151. Case II. *Given or assumed: Δ , T_1 , T_2 , and R_1 or R_2 ; to find Δ_1 , Δ_2 , and R_2 or R_1*

(a) R_1 given or assumed.

Equation 79 gives

$$\tan \frac{1}{2} \Delta_2 = \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{T_2 + T_1 \cos \Delta - R_1 \sin \Delta}$$

Then,

$$\Delta_1 = \Delta - \Delta_2$$

To find R_2 solve equation 76, and

$$R_2 = R_1 + \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{\text{vers } \Delta_2} \quad (76B)$$

(b) R_2 given or assumed.

Equation 78 gives

$$\tan \frac{1}{2} \Delta_1 = \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{R_2 \sin \Delta - T_2 \cos \Delta - T_1}$$

and

$$\Delta_2 = \Delta - \Delta_1$$

Solve equation 77, and

$$R_1 = R_2 - \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{\text{vers } \Delta_1} \quad (77B)$$

152. Case III. *Given or assumed: AB , and the angles VAB , VBA , and R_2 or R_1 ; to find Δ_1 , Δ_2 and R_1 or R_2 .*

(a) R_2 given or assumed.

Solve the triangle BAV by the sine formula for $AV = T_1$ and $VB = T_2$. The solution is then the same as that in case IIb.

(b) R_1 given or assumed.

Find T_1 and T_2 as in a; thence, as in case IIa.

153. Case IV. *Given or assumed: R_1 , R_2 , the angle Δ , and one tangent, T_1 , or T_2 ; to find the other tangent and the central angles Δ_1 , Δ_2 .*

(a) With T_1 given solve equation 76 for Δ_2 , and

$$\text{vers } \Delta_2 = \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{R_2 - R_1} \quad (76C)$$

Then, $\Delta_1 = \Delta - \Delta_2$, and T_2 is found by equation 77A.

(b) With T_2 given solve equation 77, and

$$\text{vers } \Delta_1 = \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{R_2 - R_1} \quad (77C)$$

Then, $\Delta_2 = \Delta - \Delta_1$, and T_1 is found by equation 76A.

154. Case V. *Given or assumed: Δ , one tangent, and the radius and central angle of the adjacent arc; to find the other radius and other tangent.*

(a) Given Δ , T_1 , R_1 , and Δ_1 ; to find Δ_2 , R_2 and T_2 .

Now,

$$\Delta_2 = \Delta - \Delta_1$$

Solve equation 76, whence

$$R_2 - R_1 = \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{\text{vers } \Delta_2}$$

and

$$R_2 = R_1 + \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{\text{vers } \Delta_2} \quad (76B)$$

T_2 is found from equation 77A.

(b) Given: Δ , T_2 , R_2 , and Δ_2 ; to find Δ_1 , R_1 and T_1 .

Now,

$$\Delta_1 = \Delta - \Delta_2$$

Solve equation 77, whence,

$$R_2 - R_1 = \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{\text{vers } \Delta_1}$$

and

$$R_1 = R_2 - \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{\text{vers } \Delta_1} \quad (77B)$$

T_1 is found from equation 76A.

155. General equations. Cases VI and VII may be solved by use of the general equations which will now be derived.

From Fig. 54,

$$AG = GP = t_1 = R_1 \tan \frac{1}{2}\Delta_1$$

and

$$PH = HB = t_2 = R_2 \tan \frac{1}{2}\Delta_2$$

By the law of sines,

$$\frac{T_1 - t_1}{\sin \Delta_2} = \frac{t_1 + t_2}{\sin \Delta} \quad \text{and} \quad \frac{T_1 - t_1}{\sin \Delta_2} = \frac{T_2 - t_2}{\sin \Delta_1}$$

Solving these equations for t_2 , gives

$$t_2 = \frac{(T_1 - t_1) \sin \Delta}{\sin \Delta_2} - t_1 \quad \text{and} \quad t_2 = T_2 - \frac{(T_1 - t_1) \sin \Delta_1}{\sin \Delta_2}$$

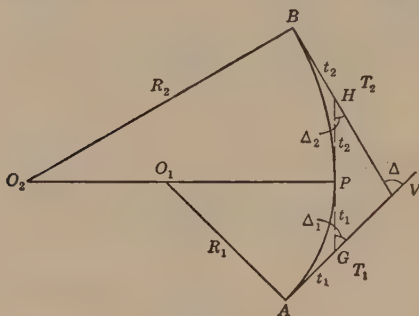


FIG. 54.

Eliminating t_2 and solving for t_1 , we have

$$t_1 = \frac{T_1(\sin \Delta + \sin \Delta_1) - T_2 \sin \Delta_2}{\sin \Delta + \sin \Delta_1 + \sin \Delta_2}$$

Substituting for t_1 its equal $R_1 \tan \frac{1}{2}\Delta_1$, gives

$$R_1 = \frac{T_1(\sin \Delta + \sin \Delta_1) - T_2 \sin \Delta_2}{\tan \frac{1}{2}\Delta_1(\sin \Delta + \sin \Delta_1 + \sin \Delta_2)} \quad (80)$$

Similarly,

$$R_2 = \frac{T_2(\sin \Delta + \sin \Delta_2) - T_1 \sin \Delta_1}{\tan \frac{1}{2}\Delta_2(\sin \Delta + \sin \Delta_1 + \sin \Delta_2)} \quad (81)$$

156. Case VI. *Given or assumed: T_1 , T_2 , Δ_1 , and Δ_2 ; to find Δ , R_1 , and R_2 .*

Find Δ from

$$\Delta = \Delta_1 + \Delta_2$$

Solve equation 80 for R_1 and equation 81 for R_2 .

Example. Given: $T_1 = 937.82$, $T_2 = 2847.51$, $\Delta_1 = 32^\circ 20'$, and $\Delta_2 = 18^\circ 10'$. Ans. $\Delta = 50^\circ 30'$; $R_1 = 719.27$; $R_2 = 9985.40$.

157. Case VII. *Given or assumed: a radius, a nonadjacent tangent, and the central angles; to find the other radius and the other tangent.*

(a) *Given: R_1 , T_2 , Δ_1 , and Δ_2 ; to find Δ , R_2 , and T_1 .*

Find Δ from

$$\Delta = \Delta_1 + \Delta_2$$

Solve equation 80 for T_1 .

$$T_1 = \frac{T_2 \sin \Delta_2 + R_1 \tan \frac{1}{2} \Delta_1 (\sin \Delta + \sin \Delta_1 + \sin \Delta_2)}{\sin \Delta + \sin \Delta_1} \quad (82)$$

Solve equation 81 for R_2 .

(b) *Given: R_2 , T_1 , Δ_1 , and Δ_2 ; to find Δ , R_1 , and T_2 .*

Find Δ from

$$\Delta = \Delta_1 + \Delta_2$$

Solve equation 81 for T_2 .

$$T_2 = \frac{T_1 \sin \Delta_1 + R_2 \tan \frac{1}{2} \Delta_2 (\sin \Delta + \sin \Delta_1 + \sin \Delta_2)}{\sin \Delta + \sin \Delta_2} \quad (83)$$

Solve equation 80 for R_1 .

FIELD WORK

158. The usual field procedure. The usual procedure for locating a compound curve in the field is very nearly the same as that used for locating a simple curve. The tangents are established in the same way, and the plus of the P.I. and the value of Δ are measured.

The remaining data required are obtained in various ways. Usually the radii of the two arcs of the curve are taken from

the map in the same way the radius of a simple curve is obtained. Unlike a simple curve, however, the value of Δ and the values of the radii of the two arcs are not sufficient to determine a compound curve (see § 146). Accordingly, in order to place the compound curve on the ground in the position shown on the map, some additional scaled value is necessary. Ordinarily, one of the central angles is measured with a protractor, or one of the tangents is scaled. With four parts thus selected the other parts may be computed, using case I or case IV.

The compound curve is so flexible that it can be used to solve many difficult location problems. For example, cases II, III, or VI would be used when the positions of the tangents could not be changed and the positions of the P.C. and the P.T. were rigidly limited by right-of-way requirements. Case V might occur in planning a structure to support a compound curve that must connect with an existing tangent where the first arc was fixed, etc.

Whatever may be the means of obtaining the necessary data, the steps for locating a compound curve under usual field conditions are the same. They are:

1. Set P.I.
2. Measure the plus of P.I.
3. Measure Δ .
4. Compute the various parts required, for example: if Δ_1 had been scaled, compute T_1 , T_2 , and Δ_2 . (Assume that the shorter arc comes first.)
5. Compute plus of P.C. = plus P.I. $- T_1$.
6. Compute $L_1 = 100\Delta_1/D_1$.
7. Compute plus of P.C.C. = plus P.C. $+ L_1$.
8. Compute $L_2 = 100\Delta_2/D_2$.
9. Compute plus of P.T. = plus of P.C.C. $+ L_2$.
10. Compute the deflection angles and subchords. The deflection angles are computed as though a tangent existed at the P.C.C. Deflections from the back tangent are used for the first arc and deflections from the common tangent at the P.C.C. are used for the second arc. The first deflection on the second arc is computed as follows:

$$b_2 = \text{plus of station following P.C.C.} - \text{plus of P.C.C.}$$

Then,

$$\frac{1}{2}d_2 = \frac{1}{2} \frac{b_2}{100} D_2$$

Thereafter, the deflections on the second arc are computed by successive additions of $\frac{1}{2}D_2$ as usual.

11. Set P.T. Measure T_2 from P.I.

12. Set P.C. Measure from nearest station.

13. Run curve: This is performed in the usual manner until the P.C.C. is located. The transit is then set up on the P.C.C. and oriented to the second arc. For this condition to be obtained, the vernier must read zero when the transit is sighted along the common tangent. Accordingly, point at any station on the first arc with the vernier set at the deflection angle of the P.C.C. minus the deflection angle of the station sighted (measured clockwise for left curves and counterclockwise for right curves), Fig. 55.

The imaginary procedure for computing this setting is the following:

Sight T , telescope reversed, vernier zero. Turn clockwise to any point C . The vernier will read the angle TBC .

$\angle TBC = \angle CAB$ both measured by one-half the same arc.

$\angle CAB$ is the difference in deflection angles between the P.C.C. and the point C on the curve.

14. Check at the P.T. for line and distance.

159. To locate a compound curve when the P.C.C. is inaccessible (Fig. 56). The curve is run in the usual manner until some station A is set short of the P.C.C. The transit is set up at A , oriented to the first arc, and turned to a deflection angle which will cause it to point along the chord AD parallel to the common tangent. It is apparent by symmetry that arc AP equals arc PB . Accordingly, if the difference between the deflections for A and P is added to the deflection for P , the deflection for B will be obtained.

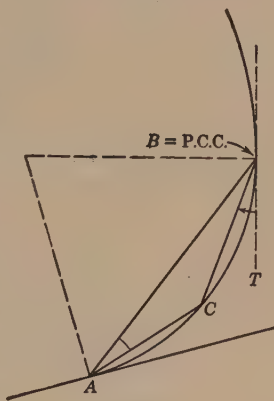


FIG. 55.

The distance AD is measured out. It is computed as follows:

$$\angle AO_1E = 2(\text{defl. } P - \text{defl. } A)$$

$$AE = R_1 \sin \angle AO_1E$$

$$EP = R_1 \text{ vers } \angle AO_1E$$

$$\text{vers } \angle EO_2D = \frac{EP}{R_2}$$

$$ED = R_2 \sin \angle EO_2D$$

$$AD = AE + ED$$

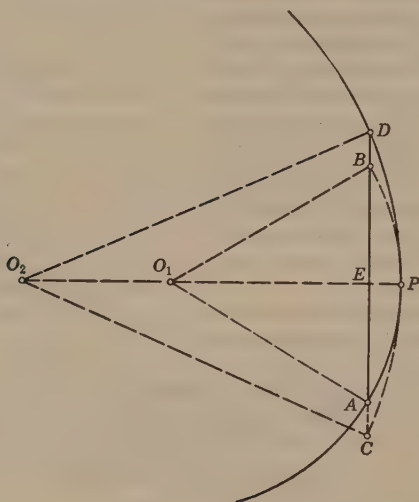


FIG. 56.

When D has been established, the transit is set up over it and oriented to the second arc as follows: sight A , telescope reversed, vernier set at the deflection angle for D but on the opposite side of zero.

It is apparent from symmetry that arc PC equals arc PD . Therefore, the change in deflection from P to C is equal to that from P to D .

The curve is continued from D in the usual way.

SPECIAL PROBLEMS IN COMPOUND CURVES

160. To compound a simple curve so that it will end in a given parallel tangent. This is capable of two types of solutions: (1) The P.C.C. can be placed where desired along the existing curve and the required new radius computed, or (2) the new radius can be selected and the required posi-

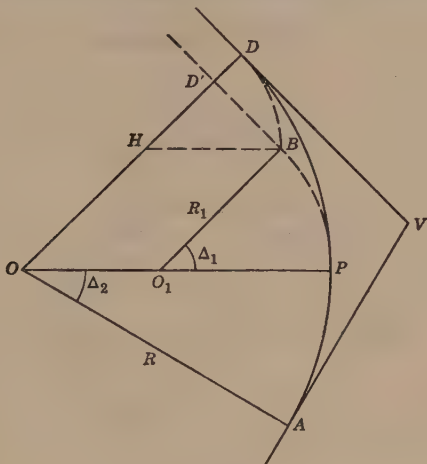


FIG. 57.

tion of the P.C.C. computed. In each type the new tangent may be inside or outside the old tangent.

(a) *Position of P.C.C. assumed, new tangent inside* (Fig. 57).

Let APD be the original simple curve with center O and radius R , and let DD' be the required distance p between the tangents. Δ_1 and Δ_2 are known from the assumed position of P . Required to find the radius R_1 of the curve PB and the distance $D'B$. Construct HB parallel to OP .

$$HB = OO_1 = R - R_1 = HD$$

$$D'D = p = (R - R_1) \text{ vers } \Delta_1$$

$$R_1 = R - \frac{p}{\text{vers } \Delta_1} \tag{84}$$

$$D'B = (R - R_1) \sin \Delta_1 \tag{85}$$

(b) *Position of P.C.C. assumed, new tangent outside* (Fig. 58); required to find R_2 and DB' .

Similarly,

$$B'B = p = (R_2 - R) \text{ vers } \Delta_2$$

$$R_2 = R + \frac{p}{\text{vers } \Delta_2} \quad (86)$$

$$DB' = (R_2 - R) \sin \Delta_2 \quad (87)$$

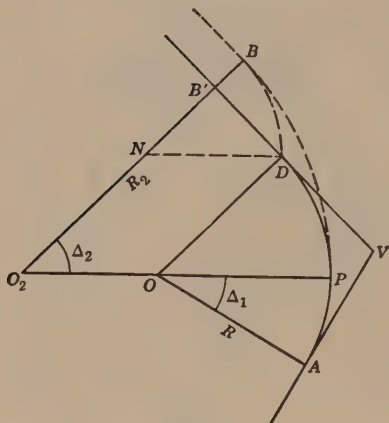


FIG. 58.

(c) *New radius selected, new tangent inside* (Fig. 57); required to find Δ_1 , Δ_2 , and $D'B$.

Solve equation 84 for Δ_1 :

$$\text{vers } \Delta_1 = \frac{p}{R - R_1} \quad (88)$$

Then, $\Delta_2 = \Delta - \Delta_1$, and find $D'B$ from equation 85.

(d) *New radius selected, new tangent outside* (Fig. 58). Required to find Δ_1 , Δ_2 , and DB' .

Solve equation 86 for Δ_2

$$\text{vers } \Delta_2 = \frac{p}{R_2 - R} \quad (89)$$

Then, $\Delta_1 = \Delta - \Delta_2$, and find DB' from equation 87.

161. *Given: a compound curve ending in a tangent; to change the P.C.C. so that a curve of same radius may end in a given parallel tangent (Fig. 59).*

Let APB be the given curve ending in VB ,
 $V'B'$ be the given parallel tangent,
 p = perpendicular distance between tangents

It is required to change the point P and with it the values of Δ_1 and Δ_2 , so that with the same radii R_1 and R_2 the new curve $AP'B'$ may end in the parallel tangent $V'B'$.

(a) *When the tangent $V'B'$ is inside VB :*

In this case since the new tangent is inside the old, there will be less space to make the turn, consequently, the sharper arc must be lengthened or the point P advanced along the line.

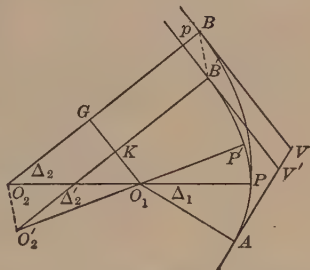


FIG. 59.

Let $\Delta_1 = AO_1P$, $\Delta_1' = AO_1P'$, $\Delta_2 = PO_2B$, $\Delta_2' = P'O_2'B'$, and in the diagram draw O_1G perpendicular to BO_2 ; then $GO_2 = O_1O_2 \cos \Delta_2$, $KO_2' = O_1O_2' \cos \Delta_2'$. Since $O_1O_2 = O_1O_2' = (R_2 - R_1)$, and $KO_2' - GO_2 = GB - KB' = p$,

$$p = (R_2 - R_1)(\cos \Delta_2' - \cos \Delta_2)$$

whence,

$$\cos \Delta_2' = \frac{p}{R_2 - R_1} + \cos \Delta_2 \quad (90)$$

$PO_1P' = (\Delta_2 - \Delta_2')$ and the point P is advanced.

(b) *When the tangent $V'B'$ is outside VB :*

In this case, the condition is the reverse of that in (a). There will be more space to make the turn, and the sharper arc must be shortened. A new figure may be constructed, or the letters V and V' , P and P' , O_2 and O_2' , and B and B' in Fig. 59 may be interchanged:

$$p = (R_2 - R_1)(\cos \Delta_2 - \cos \Delta_2')$$

whence

$$\cos \Delta_2' = \cos \Delta_2 - \frac{p}{R_2 - R_1} \quad (91)$$

$PO_1P' = (\Delta_2' - \Delta_2)$, the point P is *moved back*, and the arc AP diminished.

In case the curve terminates with the arc of shorter radius, or R_1 follows R_2 (Fig. 60)

(c) *When $V'B'$ is inside VB :*

In this case since the new tangent is inside the old and the curve ends with the sharper arc, there will be *less space* and,

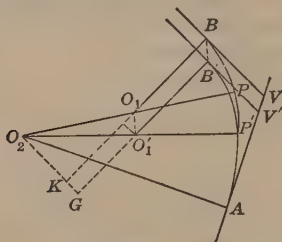


FIG. 60.

consequently, the flat arc must be shorter, with the point P brought backward to P' :

$$p = (R_2 - R_1)(\cos \Delta_1 - \cos \Delta_1')$$

whence,

$$\cos \Delta_1' = \cos \Delta_1 - \frac{p}{R_2 - R_1} \quad (92)$$

$PO_2P' = (\Delta_1' - \Delta_1)$, and the point P is *moved back*.

(d) *When $V'B'$ is outside VB :*

$$p = (R_2 - R_1)(\cos \Delta_1' - \cos \Delta_1)$$

whence,

$$\cos \Delta_1' = \cos \Delta_1 + \frac{p}{R_2 - R_1} \quad (93)$$

$PO_2P' = (\Delta_1 - \Delta_1')$, and the point P is *advanced*.

This case is the reverse of that in (c). A new figure may be sketched from the suggestion similar to that given in (b).

Example. Let $R_2 = 2292.01$, $R_1 = 1432.69$, $\Delta_2 = 28^\circ$, and $p = 20.07$ inside VB (case a).

p	20.07		$\log 1.302547$
(90) $R_2 - R_1$	859.32		$\log 2.934155$
Δ_2	28°	$\cos 0.88295$	$\log 8.368392$
$\therefore \Delta_2'$	25°	$\cos 0.906306$	
$\therefore \angle PO_1P'$	3°		

162. *Given: a compound curve terminating in a tangent; to change the P.C.C. and also the last radius, so that the curve*

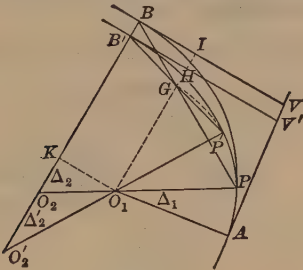


FIG. 61.

shall end in a parallel tangent at a point on the same radial line as before (Fig. 61).

Let APB be the given curve ending in the tangent VB ; let $V'B'$ be the given parallel tangent; and let $p = BB' = HI$ = the perpendicular distance between tangents.

(a) It is required to change the point P to P' and also the value of R_2 to R_2' , so that the new curve may end in $V'B'$ at B' inside VB on the same radial line BO_2 .

In the diagram produce the arc AP to G to meet O_1G drawn parallel to O_2B ; then, $PO_1G = \Delta_2$. Draw the chord PB , and it will pass through G . Lay off the distance p from B on BO_2 to find B' ; draw $B'G$, and produce it to intersect the arc APG in P' . Then P' is the P.C.C. required. Join $P'O_1$, and produce it to meet BO_2 produced in O_2' . Then $P'O_2' = B'O_2' = R_2'$, the new radius, with which describe the arc $P'B'$.

(c) When the smaller radius R_1 follows R_2 , if the given tangent $B'V'$ is inside of BV (Fig. 62):

$$\tan \frac{1}{2}\Delta_1' = \tan \frac{1}{2}\Delta_1 + \frac{p}{(R_2 - R_1) \sin \Delta_1} \quad (97)$$

$$R_1' = R_2 - (R_2 - R_1) \frac{\sin \Delta_1}{\sin \Delta_1'} \quad (98)$$

(d) If $B'V'$ is outside BV :

$$\tan \frac{1}{2}\Delta_1' = \tan \frac{1}{2}\Delta_1 - \frac{p}{(R_2 - R_1) \sin \Delta_1} \quad (99)$$

$$R_1' = R_2 - (R_2 - R_1) \frac{\sin \Delta_1}{\sin \Delta_1'} \quad (98)$$

Example 1 (Fig. 61).

Let $R_2 = 2292.01$ $p = 20.07$ inside
 $R_1 = 1432.69$ $\Delta_2 = 28^\circ$

(94)	$R_2 - R_1 =$	859.32		log 2.934155	
	Δ_2		28°	log sin 9.671609	
				2.605764	
	p	20.07		1.302547	
				8.696783	
	$\tan \frac{1}{2}\Delta_2 =$	0.24933			
		0.19958	11° 17'		
(95)	Δ_2'		22° 34'	sin 9.584058	
	$(R_2 - R_1)$			2.934155	
				3.350097	
	Δ_2		28°	sin 9.671609	
	$(R_2' - R_1)$	1051.25		3.021706	
	R_1	1432.69			

Ans. $R_2' = 2483.94 \quad \therefore D = 2^\circ 18' 25''$

$PO_1P = 28^\circ - 22^\circ 34' = 5^\circ 26' \quad \therefore PP' = 135.83 \text{ ft}$

Example 2 (Fig. 62).

Let $R_2 = 2292.01$ $p = 20.07$ inside
 $R_1 = 1432.69$ $\Delta_1 = 46^\circ$

Ans. $R_1' = 1474.41$ $\therefore D = 3^\circ 53' 12''$

$$PO_2P' = \Delta_1' - \Delta_1 = 3^\circ 07' \therefore \text{arc } PP' = \frac{3^\circ.1166}{2.5} = 124.67 \text{ ft}$$

Observe that in either figure both tangents must be on the same side of the point G , in order to reach a solution.

163. *Given: a compound curve ending in a tangent, to change the last radius and also the position of the P.C.C., so that the curve may end in the same tangent (Fig. 63).*

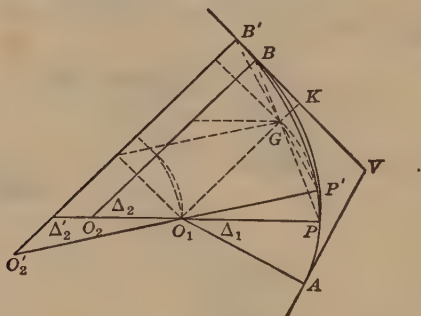


FIG. 63.

I. *When the curve ends with the greater radius R_2 :*

Let APB be the compound curve in which R_1 , R_2 , Δ_1 , and Δ_2 are known.

In the diagram draw the chord PB , and produce the first arc AP to meet it in G ; draw O_1G , and produce it to meet the tangent in K . Draw a line from G parallel to PO_2 . Then, by § 131, O_1K is parallel to O_2B , by equation 51.

$$GK = (R_2 - R_1) \text{ vers } \Delta_2 \quad (100)$$

(a) *If we assume P' as the new P.C.C., we have $\Delta_2' = P'O_2'B'$, and the chord $P'G$ produced will intersect the tangent at the new point of tangent B' , and $B'O_2' = R_2'$. Draw*

a line from G parallel to $P'O_2'$. Similar to equation 100 we have

$$GK = (R_2' - R_1) \text{ vers } \Delta_2'$$

and, equating the two expressions, we obtain

$$R_2' = R_1 + \frac{(R_2 - R_1) \text{ vers } \Delta_2}{\text{vers } \Delta_2'} = R_1 + \frac{GK}{\text{vers } \Delta_2'} \quad (101)$$

(b) If we assume R_2' , we have, from equation 101:

$$\text{vers } \Delta_2' = \frac{R_2 - R_1}{R_2' - R_1} \text{ vers } \Delta_2 = \frac{GK}{R_2' - R_1} \quad (102)$$

In the two right-angled triangles BKG and $B'KG$, we have

$$BK = GK \cot \frac{1}{2} \Delta_2$$

$$B'K = GK \cot \frac{1}{2} \Delta_2'$$

and, by subtraction,

$$BB' = GK(\cot \frac{1}{2} \Delta_2' - \cot \frac{1}{2} \Delta_2) \quad (103)$$

in which GK is obtained from equation 100.

When BB' , as given by equation 103, is *negative*, the point B' falls between B and V .

(c) If we assume the distance BB' on the tangent, we have, from the last equation,

$$\cot \frac{1}{2} \Delta_2' = \cot \frac{1}{2} \Delta_2 \pm \frac{BB'}{GK} \quad (104)$$

GK being obtained from equation 100 and R_2' from equation 101. In equation 104 use the $+$ sign when B' is beyond B as in Fig. 63.

II. When the given curve ends with the smaller radius R_1 (Fig. 64):

We have, by a similar reasoning,

$$GK = (R_2 - R_1) \text{ vers } \Delta_1 \quad (105)$$

$$R_1' = R_2 - \frac{(R_2 - R_1) \text{vers } \Delta_1}{\text{vers } \Delta_1'} = R_2 - \frac{GK}{\text{vers } \Delta_1'} \quad (106)$$

$$\text{vers } \Delta_1' = \frac{R_2 - R_1}{R_2 - R_1'} \text{vers } \Delta_1 = \frac{GK}{R_2 - R_1'} \quad (107)$$

$$BB' = GK(\cot \frac{1}{2} \Delta_1 - \cot \frac{1}{2} \Delta_1') \quad (108)$$

$$\cot \frac{1}{2} \Delta_1' = \cot \frac{1}{2} \Delta_1 \pm \frac{BB'}{GK} \quad (109)$$

using the $-$ sign when B' is beyond B .

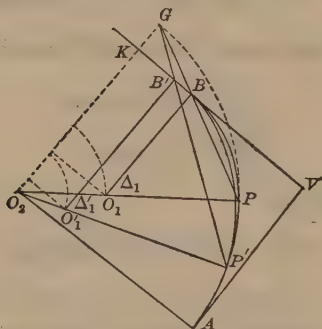


FIG. 64.

Example (Fig. 64).

Let $R_2 = 2291.01$, $R_1 = 1432.69$, $\Delta_1 = 46^\circ$, and let the P.C.C. be moved back 200 ft from P to P' ; hence, $PO_2'P' = 5^\circ$, and $\Delta_1' = 51^\circ$; to find the new radius R_1' and the distance BB' .

Use equations 105, 106, and 108.

Ans. $R_1' = 1584.16$; $D = 3^\circ 37'$; and $BB' = 68.04$.

THREE-CENTERED COMPOUND CURVES

164. *Given:* a simple curve joining two tangents; to replace it by a three-centered compound curve between the same tangent points (Fig. 65).

Let $R = AO =$ radius of simple curve

$$R_1 = PO_1 = P'O_1 < R \quad \Delta_1 = PO_1P'$$

$$R_2 = AO_2 = BO_3 > R \quad \Delta_2 = AO_2P = BO_3P'$$

$$\Delta = AOB$$

Since AO_2 is made equal to BO_3 , and $VA = VB$, AO_2P must equal BO_3P' , and the compound curve will be symmetrical

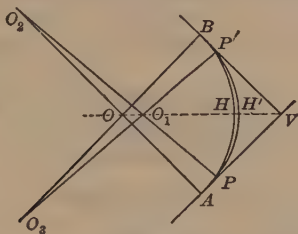


FIG. 65.

about the bisecting line VO ; and the center O_1 will be on the line VO .

We have at once, from the figure,

$$2\Delta_2 + \Delta_1 = \Delta \tag{110}$$

In the triangle OO_1O_2 we have

$$O_1O_2 : OO_2 :: \sin AOV : \sin PO_1V$$

whence,

$$R_2 - R_1 = \frac{(R_2 - R) \sin \frac{1}{2}\Delta}{\sin \frac{1}{2}\Delta_1} \tag{111}$$

which expresses the general relation between the quantities, R and Δ being given.

Various combinations may be assumed.

(a) Assume values for R_1 and R_2 subject to the foregoing conditions, namely, $R_1 < R$ and $R_2 > R$; whence

$$\sin \frac{1}{2}\Delta_1 = \frac{(R_2 - R) \sin \frac{1}{2}\Delta}{R_2 - R_1} \tag{112}$$

In selecting values for R_1 and R_2 , the degree of curve D_1 should be but little greater than D of the simple curve, say, 30 to 60 minutes, while D_2 may be taken at $\frac{1}{2}D$ to $\frac{1}{4}D$.

Example 1. Given: $R = 1719.12$; $D = 3^\circ 20'$; $\Delta = 40^\circ$.

$$\text{Let } \begin{array}{ll} R_1 = 1432.69 & D_1 = 4^\circ \\ R_2 = 5729.65 & D_2 = 1^\circ \end{array}$$

$$\therefore \begin{array}{ll} R_2 - R & 4010.53 \\ R_2 - R_1 & 4296.96 \end{array} \quad \begin{array}{l} \log 3.603202 \\ \log 3.633161 \end{array}$$

$$\frac{1}{2}\Delta \quad 20^\circ \quad \begin{array}{l} \log 9.970041 \\ \log \sin 9.534052 \end{array}$$

$$\therefore \frac{1}{2}\Delta_1 \quad 18^\circ 36' 57'' \quad \log \sin 9.504093$$

$$\Delta_1 \quad 37^\circ 13' 54''$$

$$\therefore \Delta_2 \quad 1^\circ 23' 03''$$

$$AP = P'B \text{ 138.4 ft}$$

(b) If we assume Δ_2 and R_1 , then,

$$\Delta_1 = \Delta - 2\Delta_2$$

and

$$R_2 = \frac{R \sin \frac{1}{2}\Delta - R_1 \sin \frac{1}{2}\Delta_1}{\sin \frac{1}{2}\Delta - \sin \frac{1}{2}\Delta_1} \quad (113)$$

Example 2. Given: $R = 1719.12$; $\Delta = 40^\circ$.

$$\text{Let } R_1 = 1432.69 \quad \Delta_2 = 1^\circ \quad \therefore \Delta_1 = 38^\circ$$

$$\text{Ans. } R_2 = 7387.24 \quad \therefore D_2 = 0^\circ 46\frac{1}{2}' \quad AP = 129$$

(c) Finally, we may assume Δ_2 and R_2 and deduce Δ_1 and R_1 from equations 110 and 111; but this is the least desirable because the value of R_1 so found will not usually give a convenient value to the degree of curve D_1 .

165. To determine the distance HH' between the middle points of a simple curve and a three-centered compound curve joining the same tangent points AB (Fig. 65).

In the triangle OO_1O_2 , we have

$$OO_1 = (R_2 - R_1) \frac{\sin \Delta_2}{\sin \frac{1}{2}\Delta}$$

$$HH' = OO_1 + O_1H' - OH$$

$\therefore$

$$HH' = (R_2 - R_1) \frac{\sin \Delta_2}{\sin \frac{1}{2}\Delta} - (R - R_1) \quad (114)$$

In the first example given above $HH' = 14.55$, and in the second $HH' = 17.05$ ft.

In many instances the distance HH' is so great as to render this problem *practically useless*, unless the distance HH' is discounted beforehand by putting the simple curve AHB a sufficient distance inside the proper location through the point H' . But the following problem is usually preferable.

166. *Given: a simple curve joining two tangents; to replace it by a three-centered compound curve which shall pass through the same middle point H.*

I. *The curve flattened at the tangents* (Fig. 66).

Let $R = AO$, the radius, and $\Delta =$ the central angle of the simple curve AHB , and let H be the middle point.

$$\begin{aligned} \text{Let } R_1 &= PO_1 = HO_1 & \Delta_1 &= PO_1P' \\ R_2 &= PO_2 = A'O_2 = B'O_3 & \Delta_2 &= PO_2A' = P'O_3B' \end{aligned}$$

and A' and B' be the new tangent points required.

We have at once, as in the last problem,

$$2\Delta_2 + \Delta_1 = \Delta \quad (115)$$

Since the curve is to be symmetrical about VO , $HP = HP'$, $PA = P'B$, and $AA' = BB'$.

In the diagram produce the arc HP to G , draw O_1G parallel to OA , and produce it to K . Then a tangent line at G will be parallel to VA ; and by § 131 the point G will be on the long chord HA and on the long chord PA' . GK is the perpendicular distance between parallel tangents, and the problem is similar to that given in § 164. Draw GN parallel to PO_2 and GM parallel to HO . Then by equation 51 we have, in this case,

$$GK = (R_2 - R_1) \text{ vers } \Delta_2 = (R - R_1) \text{ vers } \frac{1}{2}\Delta \quad (116)$$

for the general equation in which R and Δ are given.

Analogous to equation 103, we have

$$AA' = KA' - KA = GK \cot GA'K - GK \cot GAK$$

$\therefore$

$$AA' = GK(\cot \frac{1}{2}\Delta_2 - \cot \frac{1}{4}\Delta) \quad (117)$$

in which GK is obtained from equation 116.

Certain assumptions may be made.

(a) Assume values for R_1 and R_2 , making $R_1 < R$ and $R_2 > R$, and deduce the values of Δ_2 , Δ_1 , and AA' .

Solving equation 116 gives

$$\text{vers } \Delta_2 = \frac{(R - R_1) \text{ vers } \frac{1}{2}\Delta}{R_2 - R_1} = \frac{GK}{R_2 - R_1} \quad (118)$$

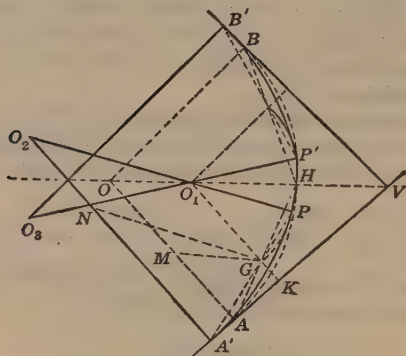


FIG. 66.

Equation 115 gives Δ_1 , and equation 107 gives AA' .

Example (Fig. 66).

Given:	$R = 764.489$	$D = 7^\circ 30'$	$\Delta = 40^\circ$
Let	$R_1 = 716.779$	$D_1 = 8^\circ$	
	$R_2 = 3437.870$	$D_2 = 1^\circ 40'$	

Use equations 116, 117, and 118.

Ans. $\Delta_2 = (\text{say}) 2^\circ 38'$; $AA' = 108.87$.

(b) Again, assume Δ_2 and $R_1 < R$; whence

$$\Delta_1 = \Delta - 2\Delta_2$$

and from equation 116,

$$GK = (R - R_1) \text{ vers } \frac{1}{2}\Delta$$

and

$$R_2 = R_1 + \frac{GK}{\text{vers } \Delta_2} \quad (119)$$

Equation 117 gives AA' .

(c) Again, we may assume Δ_2 and the distance AA' ; whence, from equation 117,

$$GK = \frac{AA'}{\cot \frac{1}{2}\Delta_2 - \cot \frac{1}{4}\Delta} \quad (120)$$

From equation 116,

$$R_1 = R - \frac{GK}{\text{vers } \frac{1}{2}\Delta}$$

Equation 119 gives R_2 .

(d) Finally, we may assume $R_1 < R$ and AA' ; then, equation 114,

$$GK = (R - R_1) \text{vers } \frac{1}{2}\Delta$$

and equation 117,

$$\cot \frac{1}{2}\Delta_2 = \cot \frac{1}{4}\Delta + \frac{AA'}{GK} \quad (121)$$

and equation 119 gives R_2 .

Example (Fig. 66).

Given: $R = 764.489$ $D = 7^\circ 30'$ $\Delta = 40^\circ$

Let $R_1 = 716.779$ $D_1 = 8^\circ$

$AA' = 110$

Use equations 121 and 119.

Ans. $R_2 = 3476.3$; $D_2 = 1^\circ 39'$; $AP' = 157.0$, $\Delta_1 = 34^\circ 46'$.

II. The curve sharpened at the tangents (Fig. 67).

This case will occur only when, with a given external distance VH , a simple curve would absorb too much of the tangents.

Let AHB be the simple curve, and $A'PHP'B'$, the required compound curve

$$R_2 = PO_2 = HO_2$$

$$\Delta_2 = PO_2P'$$

$$R_1 = PO_1 = A'O_2 = B'O_3$$

$$\Delta_1 = A'O_1P = P'O_3B'$$

From the figure,

$$2\Delta_1 + \Delta_2 = \Delta \quad (122)$$

In the diagram draw O_2G parallel to OA , cutting the tangent at K , and produce the arc HP to G . Draw the chords GH and GP , passing through A and A' , respectively. The discussion is similar to the preceding case and to the problem

§ 163, Fig. 64. Draw $A'M$ and AN parallel, respectively, to PO_2 and HO_2 . Then, we derive the general formulas:

$$GK = (R_2 - R_1) \text{vers } \Delta_1 = (R_2 - R) = \text{vers } \frac{1}{2} \Delta \quad (123)$$

and

$$AA' = GK(\cot \frac{1}{2} \Delta_1 - \cot \frac{1}{4} \Delta) \quad (124)$$

(a) If $R_1 < R$ and $R_2 > R$,

$$\text{vers } \Delta_1 = \frac{GK}{R_2 - R_1} = \frac{R_2 - R}{R_2 - R_1} \text{vers } \frac{1}{2} \Delta \quad (125)$$

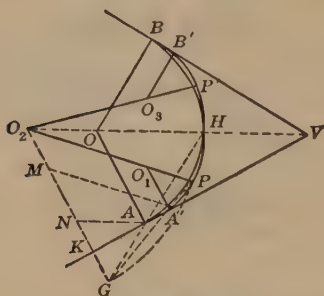


FIG. 67.

(b) If $\Delta_1 < \frac{1}{2} \Delta$ and $R_1 < R$

$$R_2 = \frac{R \text{vers } \frac{1}{2} \Delta - R_1 \text{vers } \Delta_1}{\text{vers } \frac{1}{2} \Delta - \text{vers } \Delta_1} \quad (126)$$

(c) If $\Delta_1 < \frac{1}{2} \Delta$ and AA'

$$GK = \frac{AA'}{\cot \frac{1}{2} \Delta_1 - \cot \frac{1}{4} \Delta} \quad (127)$$

$$R_2 = R_1 + \frac{GK}{\text{vers } \Delta_1} \quad (128)$$

$$R_1 = R_2 - \frac{GK}{\text{vers } \Delta_1} \quad (129)$$

(d) If $R_2 > R$ and AA'

$$GK = (R_2 - R) \text{vers } \frac{1}{2} \Delta$$

$$\cot \frac{1}{2} \Delta_1 = \cot \frac{1}{4} \Delta + \frac{AA'}{GK} \quad (130)$$

The third assumption will usually secure most readily the desired curve. AA' should be assumed as small as the nature of the case will allow, and Δ_1 should not be much smaller than $\frac{1}{2}\Delta$.

It is evidently not *necessary* that the new curve should be symmetrical; for, once the curve $A'PH$ is laid out, the simple curve HB may then be used, or, if desirable, some compound curve $HP'B'$ determined by an assumed value of BB' *not* equal to AA' .

These formulas 115 to 130 are readily adapted to the case of substituting a compound for a simple curve when it is necessary to keep one tangent point fixed, but to move the other a certain distance in either direction on the tangent. For if in Figs. 66, 67, we draw a tangent at H and make H the fixed point of tangent, it is evident that the central angle of the curve will then be AOH . The only change necessary, therefore, to adapt the formulas to this case is to write Δ in place of $\frac{1}{2}\Delta$, and to observe, instead of equations 115 and 122, that

$$\Delta_1 + \Delta_2 = \Delta$$

Example (Fig. 66).

Let $R = 1910.08 \qquad \Delta = 84^\circ$

Assume: $AA' = 260 \qquad \Delta_1 = 38^\circ \qquad \therefore \Delta_2 = 8^\circ$

Use equations 127, 128, and 129.

Ans. $R_2 = 5294.15$; $R_1 = 1193.88$; $D = 4^\circ 48'$; $A'P = 791.67$; and $PH = 369.23$.

167. *Given: two curves joined by a common tangent; to replace the tangent by a curve compounded with the given curves* (Fig. 68).

Let $R_1 = BO_1$ the radius of one curve

$R_3 = AO_3$ the radius of the other curve, $> R_1$

$l = BA$ the common tangent

$R_2 = PO_2 = P'O_2$ the radius of connecting curve

$\Delta_2 = PO_2P'$ the central angle of connecting curve

$\alpha = AO_3P'$ and $\beta = BO_1P$

$i = AO_3O_1$

In the same triangle,

$$\sin O_3O_1O_2 = \sin \Delta_2 \frac{O_3O_2}{O_1O_3} = \sin (i - \beta) \quad (133A)$$

for, from the figure $O_3O_1O_2 = i - \beta$, and taking the value of O_1O_3 from equation 132 gives

$$\sin (i - \beta) = \frac{(R_2 - R_3) \sin \Delta_2 \sin i}{l} \quad (134)$$

Having previously found i from equation 131, we obtain β and then α , since, from the figure, $\Delta_2 = \alpha + \beta$. With the angles α and β known, the points P and P' are located, and the problem is solved.

Ordinarily, this one case is sufficient for this problem, but for sake of completeness other cases are given.

Geometrical truths. Before presenting the other cases we shall now assume the following geometrical truths, which may be easily demonstrated.

If two circles intersect in one point, they intersect in two points; and the line joining the two points is the common chord.

The common chord is perpendicular to the line joining the centers, and, when produced, it bisects the common tangents.

If a third circle is drawn touching the two circles, a tangent to the third circle, parallel to the common tangent, will have its tangent point on the common chord produced.

Conversely, therefore, if the tangent BA be bisected at K , and a line KI drawn perpendicular to O_1O_3 , KI will coincide with the common chord produced, and the angle $IKA = AO_3O_1 = i$. If on KI we assume a point I through which it is desirable that the connecting curve should pass, then, I is the tangent point of a tangent parallel to BA ; consequently, a line through I perpendicular to BA contains the required center O_2 .

Case II. Let $p = HI$ = the perpendicular distance between the tangents.

If in the diagram we join IA and IB and produce the chords to intersect the given curves in P and P' , then: P and P' are the points of compound curvature; the lines PO_1 and

$P'O_3$ produced will intersect IO_2 in the same point O_2 ; and the angles $P'O_2I = \alpha$ and $PO_2I = \beta$.

In the triangle AIB the line KI bisects the base AB , and we have, by Geom. Table XLI, 25,

$$AI^2 + BI^2 = 2AK^2 + 2KI^2$$

By equation 50,

$$AI = 2(R_2 - R_3) \sin \frac{1}{2}\alpha$$

$$BI = 2(R_2 - R_1) \sin \frac{1}{2}\beta$$

$$AK = \frac{1}{2}l \quad \text{and} \quad KI = \frac{p}{\sin i}$$

$\therefore$

$$4(R_2 - R_3)^2 \sin^2 \frac{1}{2}\alpha + 4(R_2 - R_1)^2 \sin^2 \frac{1}{2}\beta = \frac{1}{4}l^2 + \frac{2p^2}{\sin^2 i}$$

Dividing by 2 and putting vers $\alpha = 2 \sin^2 \frac{1}{2}\alpha$ and vers $\beta = 2 \sin^2 \frac{1}{2}\beta$ (Table XLII, 46) gives

$$(R_2 - R_3)^2 \text{vers } \alpha + (R_2 - R_1)^2 \text{vers } \beta = \frac{1}{4}l^2 + \frac{p^2}{\sin^2 i}$$

But, by equation 51,

$$(R_2 - R_3) \text{vers } \alpha = (R_2 - R_1) \text{vers } \beta = p \quad (135)$$

$$p(2R_2 - (R_3 + R_1)) = \frac{1}{4}l^2 + \frac{p^2}{\sin^2 i}$$

$$2R_3 = (R_3 + R_1) + \frac{l^2}{4p} + \frac{p}{\sin^2 i} \quad (136)$$

From equation 135,

$$\text{vers } \alpha = \frac{p}{R_2 - R_3}; \quad \text{vers } \beta = \frac{p}{R_2 - R_1} \quad (137)$$

and, from the figure,

$$\Delta_2 = \alpha + \beta \quad (138)$$

These formulas solve the problem when p is assumed. If desirable, we may find α and β independently of R_2 , for in the triangle AIB , $IAB = \frac{1}{2}\alpha$ and $IBA = \frac{1}{2}\beta$; and, since $HK = p \cot i$,

$$\cot \frac{1}{2}\alpha = \frac{AH}{HI} = \frac{\frac{1}{2}l - HK}{p} = \frac{l}{2p} - \cot i \quad (139)$$

$$\cot \frac{1}{2}\beta = \frac{BH}{HI} = \frac{\frac{1}{2}l + HK}{p} = \frac{l}{2p} + \cot i \quad (140)$$

Case III. In case α or β is assumed, we have, from the last equation

$$p = \frac{l}{2(\cot \frac{1}{2}\alpha + \cot i)} = \frac{l}{2(\cot \frac{1}{2}\beta - \cot i)} \quad (141)$$

Remarks. For a constant value of l the less the difference of $R_3 - R_1$, the greater will be the value of the angle i . When $R_3 = R_1$, $\cot i = 0$ and $i = 90^\circ$, and the tangent point I will be on a perpendicular to BA drawn through the middle point K ; and $\alpha = \beta$. On the contrary, as $(R_3 - R_1)$ increases, i becomes less, and the foot H of the perpendicular HI moves toward B , the tangent point of the curve of smaller radius R_1 . The distance $HK = p \cot i$. The connecting curve is farthest from the tangent BA at I . To find the ordinate from BA to the curve at any other point, subtract from p the tangent offset for the length of curve from I to the ordinate in question. § 109, equation 31, may be used on flat curves with tolerable accuracy, even when the distance equals several hundred feet.

Case IV. It is evident that in this problem R_2 must be greater than either R_1 or R_3 . As the center O_2 is taken nearer the line O_1O_3 , R_2 grows less and is a minimum when O_2 falls on the line O_1O_3 . In this case we have $\Delta_2 = 180^\circ$, and

$$R_2 = \frac{1}{2}(R_3 + R_1 + O_1O_3), \text{ a minimum} \quad (142)$$

This limit must be regarded in assuming the value of R_2 . Since

$$O_1O_2 - O_2O_3 = (R_2 - R_1) - (R_2 - R_3) = (R_3 - R_1)$$

a constant value, independent of R_2 , we infer that the center O_2 is always on a hyperbola of which O_1 and O_3 are the foci; $(R_3 - R_1)$ equals the diameter on the axis joining the foci; and l equals the diameter at right angles to it, for, in the triangle O_1GO_3 ,

$$l^2 = \overline{O_1O_3}^2 - (R_3 - R_1)^2 \quad (143)$$

Example (Fig. 68).

Given: $R_1 = 1432.69$ $R_3 = 1910.08$ and $l = 400$

Assume: $p = 11.4$; to find R_2 , α and β .

Use equations 131, 136, and 137.

Ans. $i = 39^\circ 57' 34''$; $R_2 = 3439.59$, called 3437.87;
 $\alpha = 7^\circ 00'$; $\beta = 6^\circ 07'$ nearly; $\Delta_2 = 13^\circ 07'$.

Example (Fig. 68).

Given: $R_1 = 1432.69$ $R_3 = 1910.08$ and $l = 400$

Assume: $R_2 = 3437.87$; to find Δ_2 , β , α and p .

Use equations 133, 131, 134, 138, and 135.

Ans. $\Delta_2 = 13^\circ 07' 22''$; $i = 39^\circ 57' 34''$; $\beta = 6^\circ 06' 55''$;
 $\alpha = 7^\circ 00' 27''$; and $p = 11.41$.

167a. The traverse method. As in the case of simple curves, many of the problems of compound curves may be solved by the principles of the traverse. In general, the work for compound curves will fall under two heads, called the traverse of centers or the traverse of chords, and shown in Fig. 50. The reader is referred to books on surveying, under the case of supplying "missing data," for more detailed solutions, and also to Chapter XXI and § 420 of this book.

CHAPTER VII

REVERSED CURVES

168. A reversed curve is a combination of two simple curves of opposite curvature. There is a *common tangent* at their point of junction. The outer rails of the two arcs are on opposite sides of the track at the *point of reverse curve* (P.R.C.) and this calls for the elevation of both sides at the same time. As there is no opportunity of elevating the outer rail at the P.R.C., reversed curves should not be used where speed is desirable, as on main lines. They may be used to advantage in cross-overs and yard work, and are often imperative in the location of spur tracks to manufacturing or industrial plants.

Reversed curves may be divided into two general classes, according to whether the extreme tangents are parallel or diverging.

PARALLEL TANGENTS

169. *Given: the perpendicular distance p between the parallel tangents and the common radius of the reversed curve; to find the central angle of each arc.* (Fig. 69).

Let APB be the center line of the reversed curve and DG the center line between tracks.

$$AC = BC' = r, \text{ and } ACP = BC'P = \Delta_r$$

Then,

$$AD = BG = \frac{1}{2}p$$

and

$$\text{vers } ACP = \frac{AD}{CP}$$

or

$$\text{vers } \Delta_r = \frac{\frac{1}{2}p}{r} \quad (144)$$

If p and Δ_r are given, by transposing equation 144, there results

$$r = \frac{\frac{1}{2}p}{\text{vers } \Delta_r} \quad (145)$$

170. *Given: the perpendicular distance p between the parallel tangents and the radius and central angle of the first arc of the*

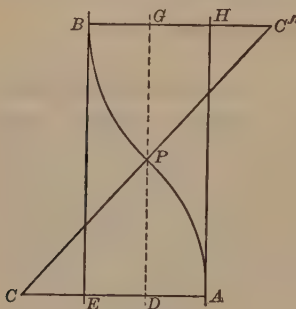


FIG. 69.

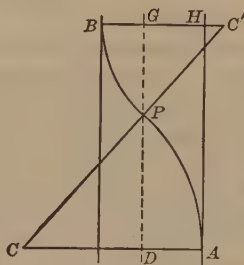


FIG. 70.

reversed curve; to find the radius of the second arc (Fig. 70).

Let APB be the center line of the reversed curve, $AC = r_1$, $BC' = r_2$, $HB = p$, $ACP = BC'P = \Delta_r$.

Draw DG through the P.R.C. and parallel to AH .

Then,

$$HB = p = AD + GB = CP \text{ vers } ACP + C'P \text{ vers } BC'P$$

or

$$p = r_1 \text{ vers } \Delta_r + r_2 \text{ vers } \Delta_r$$

from which

$$r_1 + r_2 = \frac{p}{\text{vers } \Delta_r}$$

and

$$r_2 = \frac{p}{\text{vers } \Delta_r} - r_1 \quad (146)$$

If r_1 , r_2 and p are given, Δ_r may be found by transposing equation 146, giving

$$\text{vers } \Delta_r = \frac{p}{r_1 + r_2} \quad (147)$$

With equal radii, $r_1 = r_2 = r$, and equation 149 becomes

$$r = \frac{d^2}{4p} \quad (150)$$

and equation 149 becomes

$$d = 2\sqrt{rp} \quad (151)$$

DIVERGING TANGENTS

172. *Given: the length l of the common tangent of a reversed curve and the angles of intersection with the diverging tangents;*

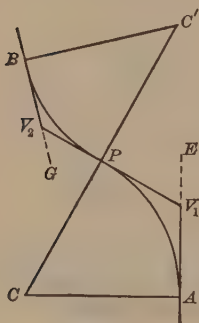


FIG. 72.

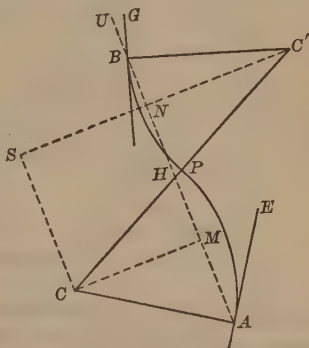


FIG. 73.

to find the common radius of a reversed curve connecting the diverging tangents (Fig. 72).

Let V_1V_2 be the common tangent of length l , AV_1 and BV_2 the diverging tangents, $EV_1P = \Delta_1$, and $GV_2P = \Delta_2$ the angles of intersection.

Then,

$$V_1V_2 = V_1P + V_2P$$

or

$$l = r \tan \frac{1}{2} \Delta_1 + r \tan \frac{1}{2} \Delta_2$$

whence

$$r = \frac{l}{\tan \frac{1}{2} \Delta_1 + \tan \frac{1}{2} \Delta_2} \quad (152)$$

Table III may be used in an approximate solution as follows: Find the tangent distances for a 1° curve with central angles of Δ_1 and Δ_2 , designating them by T_1 and T_2 . Then the desired degree of curve will be

$$D = \frac{T_1 + T_2}{l} \quad (\text{approx.})$$

173. *Given: diverging tangents, a line AB joining them, and the angles at A and B; to find the common radius of a reversed curve extending from A to B (Fig. 73).*

Let $l = AB$, and EAB and $UBG =$ the given angles A and B .

Draw CM and $C'S$ perpendicular to and CS parallel to AB .

$$\text{Let} \quad AHC = C'HB = C'CS = H$$

Then,

$$C'S = CC' \sin H = 2r \sin H$$

Also,

$$C'S = C'N + CM = r \cos B + r \cos A$$

Equating, we have

$$2r \sin H = r \cos A + r \cos B$$

or

$$\sin H = \frac{1}{2}(\cos A + \cos B)$$

Now,

$$AB = l = AM + NB + CS$$

or

$$l = r \sin A + r \sin B + 2r \cos H$$

and

$$r = \frac{l}{\sin A + \sin B + 2 \cos H} \quad (153)$$

The station of the point P may be found from the degree of curve and the central angle C which equals $90^\circ + A - H$

174. The solution of curve problems may often be simplified by measuring a certain distance, or an angle and a distance in the field.

In the case of diverging tangents for reversed curves, an easier solution may sometimes be found by prolonging one

and at a distance of p from the original tangent, the radii remaining the same (Fig. 76).

APB in Fig. 76 is the original curve; $AP'H$ the new curve; $GH = p$.

Draw $C'K$ and $C''L$ parallel to GB .

Since the radii remain the same, $KL = GH = p$.

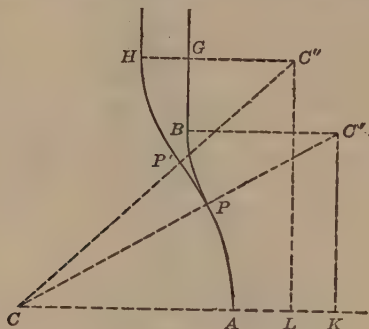


FIG. 76.

In the triangle CKC' , $CK = (r_1 + r_2) \cos KCC'$, and $CL = (r_1 + r_2) \cos KCC' - p$. From the triangle $C''CL$, $CL = (r_1 + r_2) \cos C''CL$.

Equating these two values of CL and solving yields

$$\cos C''CL = \cos KCC' - \frac{p}{r_1 + r_2}$$

The angle PCP' will locate the point P' and is equal to $C''CK - C'CK$.

The distance $PP' = 100 PCP' / d_1$, where d_1 = the degree of the first arc.

CHAPTER VIII

TURNOUTS AND CROSSINGS

TURNOUTS

178. Gauge, sometimes spelled *gage* (Fig. 77). The *gauge line* of a rail is the line of contact along the head of the rail made by the flange of the wheel. The *gauge of a track* is the perpendicular distance between the gauge lines of the two rails. The *standard gauge line* is on the inside of the rail $\frac{5}{8}$ in. below the top of rail. Standard gauge is 4 ft $8\frac{1}{2}$ in.

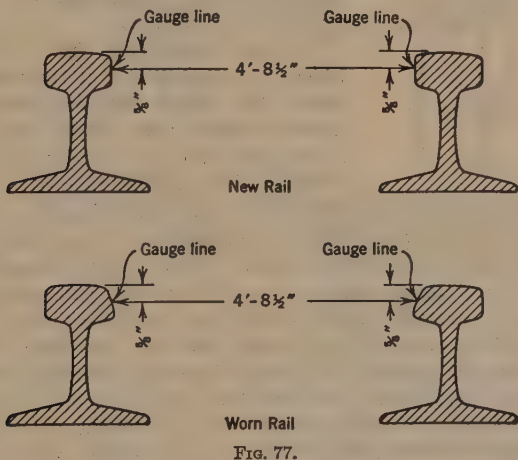


FIG. 77.

The word *gauge* is often used to mean *gauge line* as well as the *distance between gauge lines*. Unless otherwise designated, in drawings of track, all dimensions to rails refer to the gauge lines, and all lines representing rails indicate the positions of the gauge lines.

The *maximum tolerances* for standard gauge for safe operation are $+\frac{3}{4}$ in. and $-\frac{1}{4}$ in. Most railroads require the gauge to be corrected to within closer limits. Gauge is often set at 4 ft $8\frac{3}{8}$ in. on tangents and at 4 ft 9 in. on very sharp curves. It is usually held at 4 ft $8\frac{1}{2}$ in. through turnout and elsewhere.

179. A turnout is a curved track leading from one track to another. The *switch rails* are movable and, by changing their position, the train is directed to the track desired. At the point where the outer rail of the turnout crosses the rail of the main track a *frog* is introduced which allows the flanges of the wheels to pass the main rail. At points opposite the frog, guard rails are placed, their object being to prevent the wheel flanges from bearing against the frog point and also to keep them from being turned to the wrong side of the point.

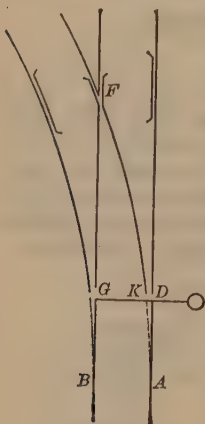


FIG. 78.

The **stub switch** (Fig. 78) is a form which is not much used at the present time. The switch rails are **common to both tracks**. One end of each rail is free and can be shifted from one track to the other as required. The

free end of the rail is called the *point or toe of switch*. The tangent point at A is called the *heel of switch*, and the distance AD is the *length of switch*. The switch rail should be several feet longer than AD or BG, and the excess should be spiked down in the line of the main track back of A or B. Then, if the switch rails are thrown over to meet the rails of the turnout, they will be sprung into arcs coinciding with those of the turnout, provided they are the proper length. The distance DK through which the point of the rail moves is called the *throw of the switch*. It varies from $4\frac{1}{2}$ to 6 in.

The **split switch** (Fig. 79) is the form most commonly used at the present time. In this form, one rail of the main track and the inner rail of the turnout are continuous. The **main track rail** from J to F and the **turnout rail** from K to F are fixed. The **switch rails**, often called **switch points**, extend from J to C and K to D. They are connected to the rails JF

and KF by joint bars at J and K , but they are free to swing about these points as pivots. They are connected to each other by one or more tie rods so that they move simultaneously. The first tie rod (at CD) is connected to the switch stand or to some other operating mechanism. The pivot end of each switch rail (at J and K) is called the **heel of switch**, and the other end (at C and D) is called the **switch point** (proper). The position *along the track* of the switch points is called the **point of switch** or P.S. The change of the position of this point due to movement of the switch rails is negligible (maximum 0.003 ft). The outer switch rail when set for the turnout makes an abrupt angle with the main track. Both switch rails are planed at one end to a wedge point $\frac{1}{4}$ in. in thickness. To prevent the inner switch rail from projecting inside the gauge rail when set for the main track, the inner stock rail of the turnout is bent at a point slightly back of the switch point. Figure 79 shows the switch set for the turnout.

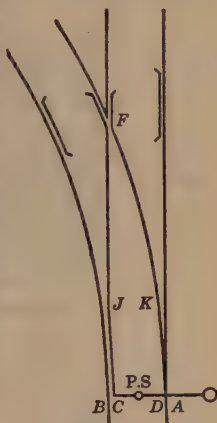


FIG. 79.

The distance gauge to gauge at the heel of the switch should be enough to allow for an angle splice and the insertion of a spike. This distance is about $6\frac{1}{4}$ in.

The lengths of switch rails on standard track range from 11 to 45 ft and over.

180. The frog. Two general types of frogs are used, the *rigid* frog and the *spring* frog. The parts of the rigid frog are shown in Fig. 80. In the rigid frog, the wing rails are both fastened securely to the main part of the frog, with sufficient clearance for the flanges of the wheel. The spring frog is used where the bulk of traffic is on the main track. The main flangeway is always open, but the other is closed to afford a continuous bearing for wheels on the main track. The movable wing is held against the point by a spring but is pushed aside by the flange of each wheel passing the frog on the turnout. Frogs may be designated by their angles, but it is customary to designate them by numbers expressing

the ratio of the bisecting line FC of the tongue to the base line ab , Fig. 81. Observe that F is at the intersection of the edges produced and not at the blunt point of the tongue. The point of intersection of the two lines is called the *theoretical*

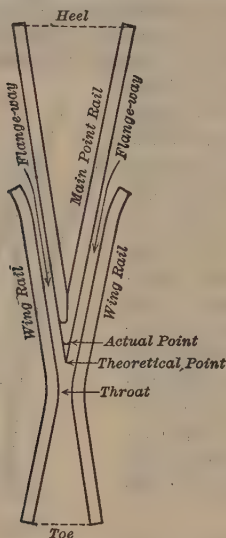


FIG. 80.

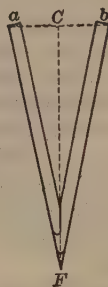


FIG. 81.

point, and the blunt is the *actual* point. The actual point is usually $\frac{1}{2}$ in. thick.

In the triangle aFC ,

$$\frac{FC}{aC} = \cot \frac{1}{2}aFb$$

and, if we let n = the number of the frog and F = the frog angle, then,

$$n = \frac{FC}{ab} = \frac{FC}{2aC} = \frac{1}{2} \cot \frac{1}{2}F \quad (158)$$

or

$$2n = \cot \frac{1}{2}F$$

If t denotes the thickness at the actual point, then, the distance between the theoretical and actual points = nt .

181. Rails in a turnout. (a) With a **stub switch** the entire line from the heel of the switch to the point of frog is a simple curve.

(b) With a **split switch** the *switch rails* and the frog rails are *straight*. This simplifies fabrication and makes it possible to use the same frog for either left or right turnouts. In special circumstances special frogs are sometimes built with curved rails.

182. Leads. The *lead* is the distance measured along the main track from switch point (in stub switch from heel of switch) to frog point. There are various kinds of leads as follows:

Stub lead. The distance (measured along the main track) from the heel of switch to point of frog is called the stub lead. If the distance is taken to the theoretic frog point, it is the theoretic lead, but, if to the actual frog point, it is called the actual lead.

Split leads. The distance from the actual switch point to theoretic frog point is the theoretic split lead and that to the actual frog point the actual split lead.

Practical leads. In order to reduce and avoid the cutting and loss of rails, the American Railway Engineering Association has adopted certain combinations of switches and frogs. These are given in Table XXIIB with some necessary quantities taken from XXIIA. A short tangent is inserted either at the heel of the switch or the toe of the frog. These tangents have an effect on the theoretic and actual split leads as before defined and give use to what may be called the *theoretic practical lead*, and the *actual practical lead*. The effect of lengthening the tangent at the heel of the switch is to lengthen the original lead, and that of lengthening the tangent at the toe of the frog is to shorten the original lead. These facts may be easily seen by simple sketches.

In the next section formulas will be derived giving the theoretic and actual split leads and then will follow the modification for the "practical leads."

183. Split switch. In the split switch both the switch rails and the frog are straight. A circular curve called the *lead curve* joins the two and is tangent to them.

Given: a straight track of gauge g , length of switch rail l , frog angle F , and number n , distance from theoretical point to

toe of frog f , distance gauge to gauge at heel of switch h , thickness of frog point t and of switch point w ; to find the lead from point of switch to the theoretical frog point and also to the actual frog point, the radius of the lead curve r , and the length of the rails between heel of switch and toe of frog (Fig. 82).

Let AK and EJ be the switch rails, DK the distance gauge to gauge at heel of switch h , and S the switch angle DAK .

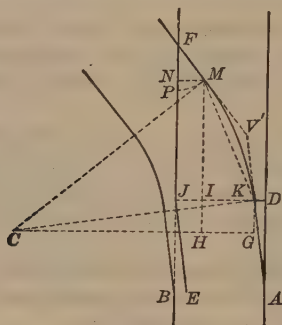


FIG. 82.

Draw the construction lines shown in the figure.

$$\sin S = \frac{h-w}{l} \quad (159)$$

The angle $V'MI = F$, and $V'MK = \frac{1}{2}(F-S)$.

$\therefore$

$$KMI = F - \frac{1}{2}(F-S) = \frac{1}{2}(F+S)$$

Now,

$$KI = DJ - DK - MN = g - h - f \sin F$$

and

$$IM = KI \cot KMI = (g - h - f \sin F) \cot \frac{1}{2}(F+S)$$

Then the theoretical lead $= L_t$ = distance from the switch point to theoretical frog point $= BF = BJ + IM + NF$ or

$$L_t = l + (g - h - f \sin F) \cot \frac{1}{2}(F+S) + f \cos F \quad (160)$$

and the actual lead $= L_a$ is

$$L_a = l + (g - h - f \sin F) \cot \frac{1}{2}(F+S) + f \cos F + nt \quad (161)$$

One value of $GH(=KI)$ has just been found. A second value is

$$GH = GC - HC = (r + \frac{1}{2}g) \cos S - (r + \frac{1}{2}g) \cos F$$

Equating these two values and solving for r give

$$(r + \frac{1}{2}g) = \frac{g - h - f \sin F}{\cos S - \cos F} = \frac{g - h - f \sin F}{2 \sin \frac{1}{2}(F - S) \sin \frac{1}{2}(F + S)} \quad (162)$$

On FB lay off the distance $FP = FM = f$. Then the distance between the heel of switch and toe of frog on main track $= JP = BF - BJ - PF$, or

$$JP = L_a - l - f - nt \quad (163)$$

This equation is independent of the radius and may be used to check a second equation as follows:

$$JP = HM - IH - PN$$

or

$$JP = (r + \frac{1}{2}g) \sin F - (r + \frac{1}{2}g) \sin S - f \text{ vers } F \quad (164)$$

The length of the curved rail KM is found by the formula,

$$KM = 0.017453(r + \frac{1}{2}g)(F - S) \quad (165)$$

in which the angle or arc $(F - S)$ is expressed in degrees.

184. *Given: the theoretical lead, the increase in lead necessary for the practical lead, and the data for the turnout; to find the length of the tangent adjacent to the heel of switch and the new radius of the outer rail (Fig. 83).*

The other given quantities are F, S, l, g, L_t, f , and h .

Let AG be the theoretical lead, $A'G$ the practical lead, $AKMF$ the outer rail of the original turnout, and $A'K''MF$ the new curve required for the practical lead. Designate $A'K''$ by l' . Draw $K'K$ parallel to AG , and connect K and M . $K'K''$ is to be found.

The length of switch rail is the same in the two turnouts as is the distance gauge to gauge at heel of switch; consequently, the central angle of the two arcs will each be equal

reduced by this value, we get the *radius of the new turnout curve*,

$$(r + \frac{1}{2}g) = \frac{g - h - f \sin F - (l' - l) \sin S}{2 \sin \frac{1}{2}(F - S) \sin \frac{1}{2}(F + S)} \quad (167)$$

185. *Given: the theoretical lead, the decrease in lead necessary for the practical lead, and the data of the turnout; to find the length of the tangent adjacent to the toe of the frog and the new radius of the outer rail (Fig. 84).*

The given quantities are the same as in § 184.

Designate FP' by f' . Now, $PP' = A'A$. $P'M$ is to be found.

Solve the triangle $MP'P$ in a similar way to that in the previous section.

$$P'M = f' - f = \frac{A'A \sin \frac{1}{2}(F + S)}{\sin \frac{1}{2}(F - S)} \quad (168)$$

Also, if the numerator of equation 162 is reduced by $(f' - f) \sin F$, it becomes $g - h - f' \sin F$, giving the radius of the new turnout curve,

$$(r + \frac{1}{2}g) = \frac{g - h - f' \sin F}{2 \sin \frac{1}{2}(F + S) \sin \frac{1}{2}(F - S)} \quad (167A)$$

186. In case of a double turnout from the same switch three frogs are required, and the switch is called a *three-throw* switch, because its points take three different positions. When split switches are used for such a combination, it is advisable to have the second set of switch rails placed slightly in advance of the first set. This form is termed a *tandem* switch.

Given: the equal frog angles F and F' of a tandem split switch, the distance d from one point of switch to the other, the radius r of the two curves, and the length l of both switch rails; to find the angle of the crotch frog F'' and the crotch frog distance (Fig. 85).

The rails of the main track frogs and the switch rails will be considered straight, while the crotch frog rails will be taken as curved.

Let AKF and $BK'F'$ be the outer rails of the double turnout, whose radii, CF'' and $C'F'' = r + \frac{1}{2}g$.

Produce each curve backward until it becomes parallel to the main track rails at the points G and G' . Draw $C'G'$ to

meet CP drawn parallel to AF' . Designate the distances from G and G' to the main track rails by o , and from the figure,

$$o = h - (r + \frac{1}{2}g) \text{ vers } S \quad (169)$$

where h = distance gauge to gauge at heel of switch, and S = the switch angle.

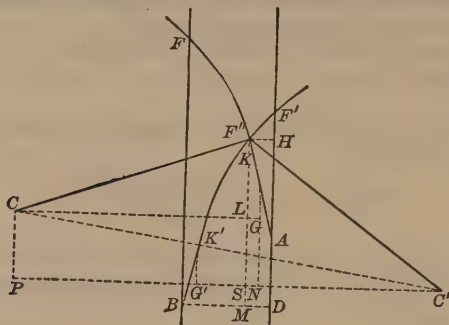


FIG. 85.

Solve the right triangle CPC' for $CC'P$ and CC' , where

$$CP = GN = AD = d$$

and

$$PC' = CG + C'G' - G'N$$

$$= (r + \frac{1}{2}g) + (r + \frac{1}{2}g) - (g - 2o) = 2(r + o)$$

Then, in the isosceles triangle $CF''C'$,

$$\cos F''CC' = \frac{\frac{1}{2}CC'}{CF''} = \frac{\frac{1}{2}CC'}{r + \frac{1}{2}g} \quad (170)$$

and the crotch frog $F'' = 2F''CC'$.

The crotch frog distance $DH = F''S + SM$.

Now,

$$F''S = (r + \frac{1}{2}g) \sin F''C'S$$

and

$$SM = l - (r + \frac{1}{2}g) \sin S$$

$\therefore$

$$DH = (r + \frac{1}{2}g) \sin F''C'S + l - (r + \frac{1}{2}g) \sin S \quad (171)$$

$$BF = L_s = AB \cot BFA = g \cot \frac{1}{2}F \quad (173)$$

Also,

$$BF = L_s = FC \sin FCB = (r + \frac{1}{2}g) \sin F \quad (174)$$

From the isosceles triangle aCf ,

$$af = 2r \sin \frac{1}{2}F \quad (175)$$

Similar to equation 172, we have

$$\text{vers } ACK = \frac{DK}{CA} = \frac{DK}{(r + \frac{1}{2}g)}$$

Also,

$$AD = (r + \frac{1}{2}g) \sin ACK$$

But, since the inside rail has the same throw as AD , while its radius is $(r - \frac{1}{2}g)$, we may drop the $\frac{1}{2}g$; hence, the length of the switch rails is

$$AD = r \sin ACK \quad (\text{approx.}) \quad (176)$$

Second, formulas containing n. From the triangle BFA ,

$$BF = L_s = AB \cot BFA = g \cot \frac{1}{2}F$$

But, from equation 158,

$$\cot \frac{1}{2}F = 2n$$

$$BF = L_s = 2gn \quad (177)$$

From the triangle BFC ,

$$BF^2 = FC^2 - BC^2$$

or

$$BF^2 = L_s^2 = (r + \frac{1}{2}g)^2 - (r - \frac{1}{2}g)^2 = 4g^2n^2$$

whence

$$2gr = 4g^2n^2$$

or

$$r = 2gn^2 = L_s n \quad (178)$$

Draw the line CM bisecting af . Then, the triangle aCM and ABF are similar, and

$$aM:aC::AB:AF$$

or

$$\frac{1}{2}af:r::g:AF$$

$\therefore$

$$af = \frac{2gr}{AF}$$

but

$$AF = \sqrt{BA^2 + BF^2} = \sqrt{g^2 + 4g^2n^2} = g\sqrt{1+4n^2}$$

Consequently,

$$af = \frac{2r}{\sqrt{1+4n^2}} \quad (179)$$

From equation 32, the throw

$$DK = t = \frac{AD^2}{2r}$$

$\therefore$

$$l = AD = \sqrt{2rt} \quad (180)$$

Table XXII has been calculated by the preceding formulas. This table applies only to *stub switch turnouts*.

188. Offsets for constructing turnouts. The position of the main track and the location of the frog on it depend on requirements exterior to the turnouts and are determined according to principles developed in later paragraphs. When the main track and the frog are in position, the remainder of the turnout is built by measurements from them. For this purpose, a system of plusses and offsets should be computed. The plusses are measured along the main track rail, and the offsets are measured between the gauge line of the main track rail and the gauge line of the turnout rail, as shown in Fig. 87. The places where the offsets are taken vary with practice. One system is given here.

Figure 87 applies to a split switch. The curve KM is produced backward through the angle S where it becomes parallel to the main track rail AD . Divide KM into four parts, and through each point of division draw lines perpendicular to AD .

From equation 169,

$$VW = o = DK - (r + \frac{1}{2}g) \text{ vers } S = h - (r + \frac{1}{2}g) \text{ vers } S$$

$$\text{Angle } KCM = (F - S)$$

$$WCS = S + \frac{1}{4}(F - S) \quad WCT = S + \frac{1}{2}(F - S)$$

$$WCU = S + \frac{3}{4}(F - S) \quad WCM = S + (F - S) = F$$

Then, $AD = l$ approx., and

$$VA = VD - AD = (r + \frac{1}{2}g) \sin S - l = q$$

Note that V will fall *between* A and D with long switch rails. Now,

$$AS' = (r + \frac{1}{2}g) \sin WCS - q$$

and

$$S'S = (r + \frac{1}{2}g) \text{ vers } WCS + o$$

Similar expressions may be given for AT' and $T'T$, AU' and $U'U$, and so on.

Table XXIIB gives the coordinates of the quarter points of the different lead curves.

With a *stub switch* the offsets may be found by the methods of §§ 111 and 112.

When a tangent is introduced beyond the heel of the switch, the value of o from equation 169 will be

$$o = h + (l' - l) \sin S - (r + \frac{1}{2}g) \text{ vers } S \quad (169A)$$

Third, once the switch rails and the frog have been placed, the lead curve connecting the two may be located by taking offsets from the long chord of the curve. The length of the long chord of the outer rail of a *split* switch is deduced from Fig. 83 and is $KM = 2(r + \frac{1}{2}g) \sin \frac{1}{2}(F - S)$. The values of the offsets may be found by the methods of §§ 115 to 120. As applied to the *stub switch*, the middle ordinate of the long chord AF (Fig. 86) is $\frac{1}{4}g$, and the ordinates at the quarter points are $\frac{3}{16}g$.

The track beyond the heel of the frog will assume one of the following forms. It may be straight, or there may be a combination of curves and tangents; it may be part of a cross-over between parallel tracks; or it may be extended to a parallel side track.

In case of an existing frog, the method of procedure is illustrated by Fig. 88. A tangent at the frog point is located by sighting along the line $F'G$ with the angle F laid off on the proper side of zero. The tangent being located, the work proceeds as in any straight-line or curve work.

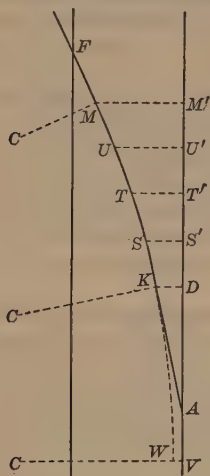


FIG. 87.

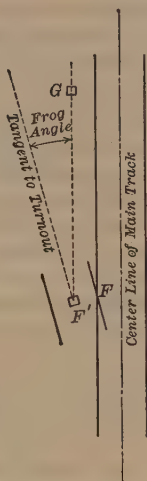


FIG. 88.

With a new track, the intersection of the main track and side track is found, and the turnout frog and other points are found from computed coordinates.

FIELD PROCEDURE FOR ESTABLISHING A TURNOUT

189. Standard turnout data. It is evident from the foregoing paragraphs that, when n , f , and the length of track rails are known, a turnout can be completely designed, and all the data required to build it can be computed. It is the practice of railroad companies to choose as standard certain frog numbers and certain types of frogs having these numbers. The turnout data, including the plusses and offsets, for each of these standard frogs are computed once and for all and made

available to all persons concerned. Thus, when the center line of the main track is indicated on the ground (or the track is actually in place) and a standard frog is specified, the entire turnout can be laid out by simple tape measurements from a mark which shows the position of the frog.

It is customary to mark the frog position by setting a stake on the center line of the main or the side track opposite the position of the actual frog point or, if track is in place, to mark this position on the rail.

190. The choice of frog depends on the service the turnout will perform. On main track, the speed and density of train operation controls the choice. Larger numbers are used for higher speeds, hard center frogs for heavy traffic, spring frogs on important track, and so on. In yards and sidings the frog must not require a lead curve that is so sharp that the middle flangeless drivers might drop off inside the curve of the rails. *See Tables XXIIA and B.*

191. Methods of determining the position of the frog. The position of the frog depends on the track with which the turnout will connect. Frequently the position of the frog must be established as accurately as possible, sometimes it may be placed within closely defined limits, and often it may be located by eye. Accordingly, rigid formulas are used where necessary, and approximate methods which are easier to use are adopted where allowable. In complicated cramped locations, graphical methods must be depended on.

The frog must be placed so that the most advantageous connecting track results. This track, as a rule, must have at least the minimum radius which can be negotiated by a road engine and usually the largest radius possible without interfering with the facilities served. Spirals are seldom necessary and should be used only when plenty of room is available. They always increase the length of the connecting track or reduce the radius.

192. The elements of a turnout. Figure 89 illustrates the elements of a turnout which are used in the determination of a frog position.

A is the point of intersection of the center lines of the two frog tracks.

B and *G* are center-line points opposite the theoretical frog point.

B' and G' are center-line points opposite the actual frog point.

D and E are the first points on the center line where curved track can start beyond the turnout. They are therefore the P.C. or P.T. of a curve. Where space is limited they are placed opposite the heel of the frog, as shown. Where space is not closely limited, a length up to 10 ft should be added to the tabulated value of k . This introduces a short tangent beyond the heel and reduces the maintenance necessary to avoid a kink forming at the heel. For purposes of computation, it is merely assumed that the value of k is increased by the length of this added tangent. D and E will then indicate the ends of the new value of k and Fig. 89 remains unchanged.

P.S. is the point of switch, that is, the center-line point opposite the switch points.

M'' is the center-line point on the main track opposite the toe of the frog.

Note. When the main track is curved, the center line of the turnout from P.S. to M'' is curved. The turnout rails can be located from the curved main rails using the same offsets which are computed for straight track (as given in § 188 and Fig. 87). The theoretical error, thus introduced, is negligible.

From Fig. 89,

$$AB = AG = \frac{1}{2}g \cot \frac{1}{2}F$$

By equation 158,

$$n = \frac{1}{2} \cot \frac{1}{2}F$$

By substitution,

$$AB = AG = ng$$

From Fig. 89,

$$S = L_t - ng$$

and

$$K = AD = AE = ng + k$$

and

$$S + K = L_t + k$$

From Fig. 89,

$$CD = CE = K \tan \frac{1}{2}F = \frac{K}{\cot \frac{1}{2}F}$$

From equation 158,

$$2n = \cot \frac{1}{2}F$$

By substitution,

$$CD = CE = \frac{K}{2n}$$

In like manner,

$$BB' = CC' = nt \quad (\text{very nearly})$$

193. Procedure for laying out a turnout. After the center line of the main track is marked, the usual procedure for laying out a turnout consists of the following steps:

1. Compute (or estimate) the position of *A* along the center line of the main track. This depends on the requirements exterior to the turnout.

2. Set point *A*.

3. Set up the transit at *A* and set *B'* and *D*.

4. Turn off the frog angle *F* and set *G'* and *E*.

(These four steps completely locate the frog and also locate the tangents to the tracks connecting with the turnout.)

5. When the frog and the unbroken main track rail have been spiked in place, line the outside turnout lead rail by offsets (as in Fig. 87).

6. Line the inside turnout rail by gauging from the outside rail.

It is frequently possible to omit setting the point *A* and, instead, to set point *B'* immediately.

The detailed procedure for actually building the turnout is not within the scope of this text.

194. Methods of locating the point *A*. The problem of locating point *A* from the requirements exterior to the turnout appears in many forms. The following paragraphs cover the usual forms of this problem.

TURNOUTS FROM STRAIGHT TRACK

195. Turnout to a siding (Fig. 90). *AV* represents the main track. *HJ* represents the required position of a siding. *H* is the limit of curved track. (It is limited here by the posi-

Solve equation 182:

$$AV = \frac{K \sin (\Delta - F) + r \text{ vers } (\Delta - F)}{\sin \Delta} \quad (184)$$

Case II. *Given:* AV ; *to find* r , HV .

Solve equation 182:

$$r = \frac{AV \sin \Delta - K \sin (\Delta - F)}{\text{vers } (\Delta - F)} \quad (185)$$

Solve equation 181:

$$HV = \frac{K \sin F + r(\cos F - \cos \Delta)}{\sin \Delta} \quad (186)$$

Case III. *Given:* r ; *to find* AV , HV .

Use equations 184 and 186.

Note: Case I occurs when the largest possible radius for the connecting curve is desired. A large radius facilitates operation and reduces the possibility of derailment when the curve gets out of alignment. Case II occurs when the frog is in place or its position is otherwise established and the largest possible radius for the connecting curve is desired. Case III occurs when the maximum length of straight siding is desired. r in case III is the minimum allowable radius.

196. Turnout to a siding, approximate method (Fig. 91). P represents P.S. (Point of Switch).

1. Set V .
2. Measure HV and Δ .
3. Assume that $PV = HV$.
4. Compute $DV = PV - L$.
5. Set D by measuring approximately DV , from V , placing D at a joint or otherwise convenient location.
6. Set A , E , P.I.; measure E to P.I. and H to P.I.
7. Choosing E to P.I. or H to P.I., whichever is smaller, and using this value for T , compute

$$r = T \cot \frac{1}{2}(\Delta - F)$$

8. Using the next larger convenient degree of curvature, compute the curve, set the P.T. and the P.C., and run the curve in the usual way. ¶

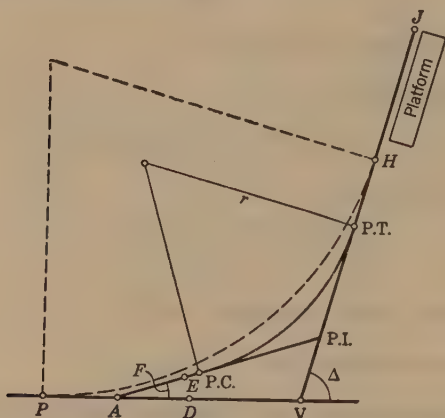


FIG. 91.

197. Cross-overs and connecting tracks. A cross-over is a track connecting turnouts which are on two parallel tracks. The parallel tracks may be either straight or curved. A connecting track is a track connecting turnouts on two nonparallel tracks which may be either straight or curved.

A cross-over or a connecting track may have any alignment desired but certain desirable features can be obtained only when one of the four following combinations is used:

1. **Straight track** (Fig. 92). *This gives a simple connection.* It can only be used on cross-overs between parallel straight tracks where the frog numbers are the same. It might occur by chance in other combinations of track alignment.

2. **A simple curve** beginning at the heel of one frog and ending at the heel of the other frog (Figs. 93–95). *This gives the maximum radius for the connection without unduly increasing the distance between turnouts.*

3. **A simple curve and a tangent** (Fig. 96). *This simplifies computation.*

4. A reversed curve (Figs. 97–99). This reduces the distance between turnouts. If the reversed curve has equal radii, the maximum radius is obtained for the reduction obtained.

198. Coordinates for cross-overs. Certain cross-overs are used so frequently that many railroads publish the plusses and offsets by which they can be located in the field. These coordinate values are computed after the solutions described in the following paragraphs have been completed.

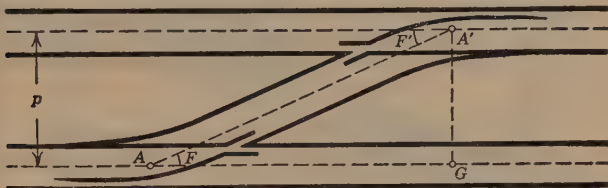


FIG. 92.

199. Cross-over by a straight track. Given the perpendicular distance p between two parallel straight tracks, to find the distance AG along the center lines of the tracks between the points A and A' of the turnouts (Fig. 92).

From the figure,

$$F' = F$$

$$AG = p \cot F \quad (187)$$

200. Cross-over by a simple curve connecting different frogs on parallel straight tracks (Fig. 93). *Given:* the perpendicular distance p between the two parallel straight tracks; to find the radius r of the connecting curve and the distance AG along the center lines of the tracks between the points A and A' of the turnouts.

Construct JJ' perpendicular to JA and $J'A'$, and project points on JJ' as shown.

From the figure,

$$QH' = r \text{ vers } F$$

$$Q'H' = r \text{ vers } F'$$

$$Q'J' = K' \sin F'$$

$$QJ = K \sin F$$

$$p = r \text{ vers } F - r \text{ vers } F' + K \sin F + K' \sin F'$$

$$r = \frac{p - K \sin F - K' \sin F'}{\text{vers } F - \text{vers } F'} \quad (188)$$

Similarly, by projecting on AJ ,

$$AG = r(\sin F - \sin F') + K \cos F + K' \cos F' \quad (189)$$

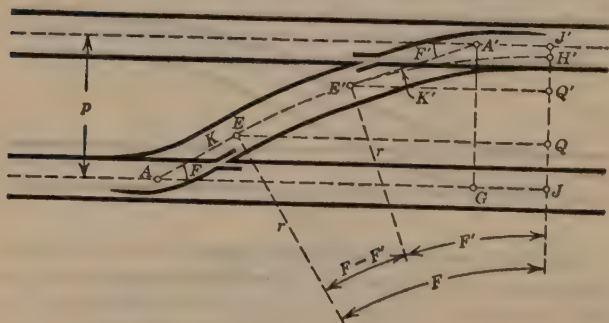


FIG. 93.

201. Connecting track by a simple curve connecting nonparallel straight tracks (Fig. 94). VA and VA' represent the center lines of nonparallel tracks making an angle β with each other and connected by the cross-over $AEE'A'$.

Angle β and the length of d (GA) must be determined by design or by field measurement. d is the perpendicular to GA' from A . Any convenient parts of the right triangle VAG can be measured or computed to determine β and d .

Given: β and d ; to find r and GA' .

Construct AJ parallel to GA' , and project points on GA , as shown.

It is evident that this problem is similar to the problem in § 200 with $F - \beta$ substituted for F , d for p , and GA' for AG .

From the figure,

$$\Delta = F - \beta$$

$$d = r \text{ vers } \Delta - r \text{ vers } F' + K \sin (F - \beta) + K' \sin F'$$

Solving for r gives

$$r = \frac{d - K \sin (F - \beta) - K' \sin F'}{\text{vers } \Delta - \text{vers } F'} \quad (190)$$

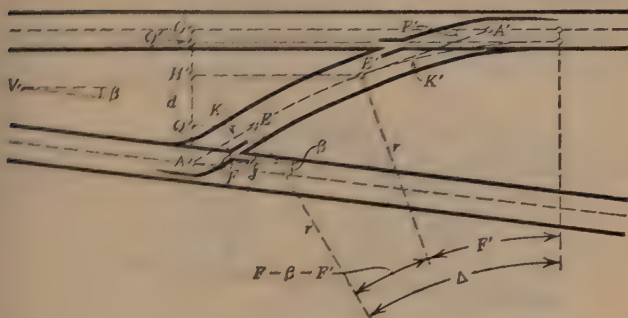


FIG. 94.

Similarly, by projecting on GA' ,

$$GA' = r(\sin \Delta - \sin F') + K \cos (F - \beta) + K' \cos F' \quad (191)$$

When the curvature of the connecting track takes the opposite direction, a slightly different formula will avoid difficulties with signs (Fig. 95).

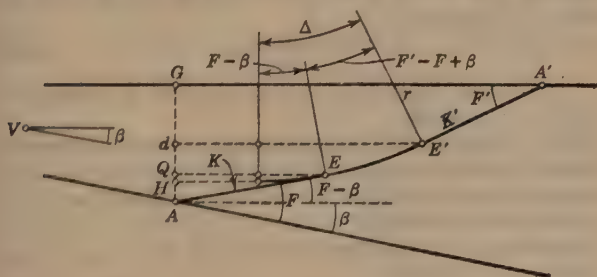


FIG. 95.

From the figure,

$$\Delta = F'$$

$$d = r[\text{vers } \Delta - \text{vers } (F' - \beta)] + K \sin (F - \beta) + K' \sin F'$$

Solving for r gives

$$r = \frac{d - K \sin (F - \beta) - K' \sin F'}{\text{vers } \Delta - \text{vers } (F - \beta)} \quad (190A)$$

Similarly,

$$GA' = r[\sin \Delta - \sin (F - \beta)] + K \cos (F - \beta) + K' \cos F' \quad (191A)$$

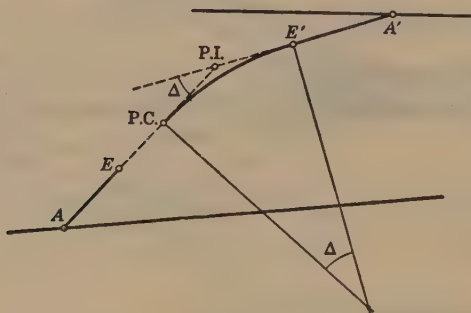


FIG. 96.

202. Connecting track by a simple curve between frogs in place (Fig. 96).

P.I. is set by extending AE and $A'E'$, and Δ is measured. Choosing E to P.I. or E' to P.I., whichever is shorter, for the value of T , compute:

$$r = T \cot \frac{1}{2} \Delta \quad (21)$$

A convenient degree of curvature may then be chosen and the curve computed.

203. Cross-over by a reversed curve connecting parallel straight tracks (Fig. 97). JG and $J'A'$ are the center lines of parallel tracks separated by the distance p and connected by the cross-over $AE'E'A'$.

Construct JJ' perpendicular to JG and $J'A'$, and project points on JJ' as shown.

By § 170,

$$HH' = (r + r') \text{vers } \Delta$$

Also,

$$QH = r \text{vers } F, \quad Q'H' = r' \text{vers } F'$$

$$QJ = K \sin F, \quad Q'J' = K' \sin F'$$

Then,

$$p = (r+r') \text{ vers } \Delta - r \text{ vers } F - r' \text{ vers } F' + K \sin F + K' \sin F' \quad (192)$$

In like manner, by projection on JG ,

$$AG = (r+r') \sin \Delta - r \sin F - r' \sin F' + K \cos F + K' \cos F' \quad (193)$$

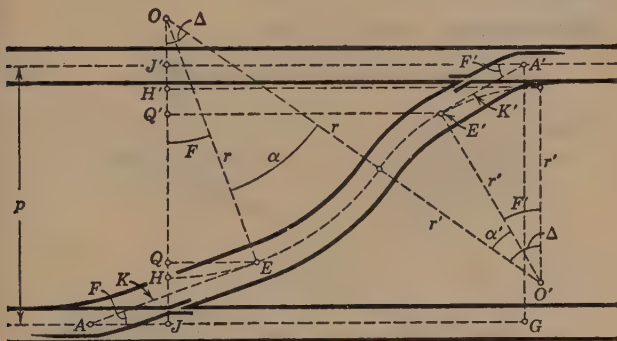


FIG. 97.

Case I. *Given: r and r' ; to find α and α' and the distance AG .*
Solve equation 192:

$$\text{vers } \Delta = \frac{p + r \text{ vers } F + r' \text{ vers } F' - K \sin F - K' \sin F'}{r + r'} \quad (194)$$

$$\alpha = \Delta - F$$

$$\alpha' = \Delta - F'$$

Use equation 193 to find AG .

Case II. *Given: r and α ; to find r' and α' and the distance AG .*

Solve equation 192:

$$\Delta = \alpha + F$$

$$r' = \frac{p - r(\text{vers } \Delta - \text{vers } F) - K \sin F - K' \sin F'}{\text{vers } \Delta - \text{vers } F'} \quad (195)$$

Use equation 193 to find AG .

Case III. Usually $r = r'$ is given, and the two frogs used are the same; required $\alpha = \alpha'$ and AG .

Substituting in equation 194 yields

$$\text{vers } \Delta = \frac{\frac{1}{2}p + r \text{ vers } F - K \sin F}{r} \quad (196)$$

$$\alpha = \Delta - F$$

Substituting in equation 193 gives

$$\frac{1}{2}AG = r(\sin \Delta - \sin F) + K \cos F \quad (197)$$

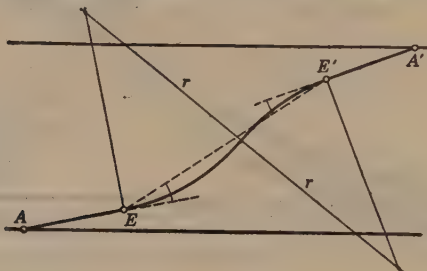


FIG. 98.

Case IV. When the two frogs are in place, they should be connected by a reversed curve of the largest radius possible (Fig. 98).

Measure EE' and the angles at E and E' , respectively. Apply § 173.

204. Connecting track by a reversed curve between nonparallel straight tracks (Fig. 99). VA and VA' represent the center lines of nonparallel tracks making an angle β with each other and connected by the cross-over $AE E' A'$.

Angle β and the length of d (GA) must be determined by design or by field measurement. d is the perpendicular to GA' from A . Any convenient parts of the right triangle VAG can be measured or computed to determine β and d .

Construct AJ parallel to GA' , and project points on GA , as shown.

It is evident that this problem is similar to the problem in § 203 with $F - \beta$ substituted for F , d for p , and GA' for AG .

From the figure,

$$d = (r+r') \text{ vers } \Delta - r \text{ vers } (F-\beta) - r' \text{ vers } F' + K \sin (F-\beta) + K' \sin F' \quad (198)$$

In like manner, by projecting on GA' ,

$$GA' = (r+r') \sin \Delta - r \sin (F-\beta) - r' \sin F' + K \cos (F-\beta) + K' \cos F' \quad (199)$$

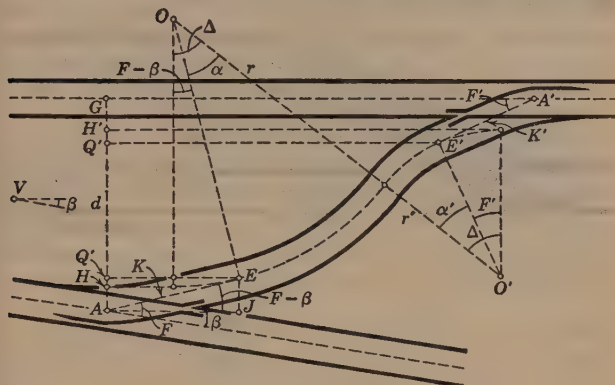


FIG. 99.

Case I. *Given: r and r' ; to find α and α' and the distance GA' .*

Solve equation 198:

$$\text{vers } \Delta = \frac{d + r \text{ vers } (F-\beta) + r' \text{ vers } F' - K \sin (F-\beta) - K' \sin F'}{r+r'} \quad (200)$$

$$\alpha = \Delta - (F-\beta)$$

$$\alpha' = \Delta - F'$$

Use equation 199 to find GA' .

Case II. *Given: r and α ; to find r' and α' and the distance GA' .*

$$\Delta = \alpha + F - \beta$$

Solve equation 198:

$$r' = \frac{d - r[\text{vers } \Delta - \text{vers } (F - \beta)] - K \sin (F - \beta) - K' \sin F'}{\text{vers } \Delta - \text{vers } F'} \quad (201)$$

Use equation 199 to find GA' .

Case III. Usually $r = r'$ is given, and the two frogs used are the same. Required α , α' , and GA' . Solve as in case I.

Case IV. When the two frogs are in place, the problem is solved in the same manner as case IV in § 203.

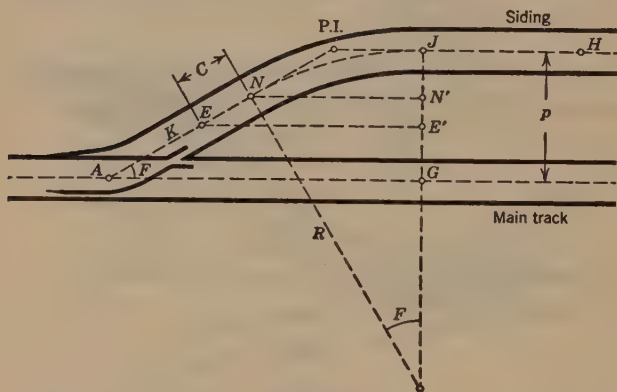


FIG. 100.

205. Turnout from a straight track to a parallel side track (Fig. 100). AG represents the main track, JH the side track, p is the required center line clearance, R the radius of the connecting curve, and C (EN) the tangent between the heel of the frog at E and the P.C. of the curve.

From the figure by projection on JG :

$$p = K \sin F + C \sin F + R \text{ vers } F \quad (202)$$

Case I. Often a minimum radius is selected, and the value of C is computed. Given: R ; to find C .

Solve equation 202 for C :

$$C = \frac{p - R \text{ vers } F}{\sin F} - K \quad (203)$$

Case II. *Often the largest possible radius is desired. C is then given the value zero, and the value of R is computed. Given: $C = 0$; to find R .*

Solve equation 202 for R :

$$R = \frac{p - K \sin F}{\text{vers } F} \quad (204)$$

Coordinates. Most railroad companies reduce these data to the form of plusses and offsets for various standard turnouts and track center-line spacings so that the turnout can be laid out with a tape alone. The coordinates thus computed can be used on light curves as well.

206. Yard tracks. Yard designs include many types of track arrangement, depending on the space available and the operations the yard is to serve. The track arrangement is controlled by the required clearances between track, the minimum radius that can be used, and the minimum separation between turnouts. Three types of track arrangement are used as examples. They should prove sufficient to illustrate the principles necessary to determine track positions for most yards.

A yard consists of a series of parallel tracks called **body tracks**, a through track built beside the body tracks called a **main yard track** or a **run-around track**, and a track at one or both ends of the yard called a **ladder track** which connects the main yard track with all the body tracks (Figs. 102, 103, and 104).

The controlling factors in yard design are the following:

1. **Center-line clearances between body tracks**, denoted by p and **center-line clearances between the main and the adjacent body track** denoted by p_1 . To conserve space, both clearances are made equal to the minimum values consistent with safety. p_1 is usually larger than p because of the higher speeds on the main track.

2. **The radii r of lead curves and the radii R of the connecting curves.** These radii must be as short as possible to conserve space but long enough to avoid derailment. Generally one value is used for both, but lead curves can safely have slightly shorter radii than connecting curves. The radius of the lead curve chosen determines the turnout available and, hence, the frog angle used throughout the yard.

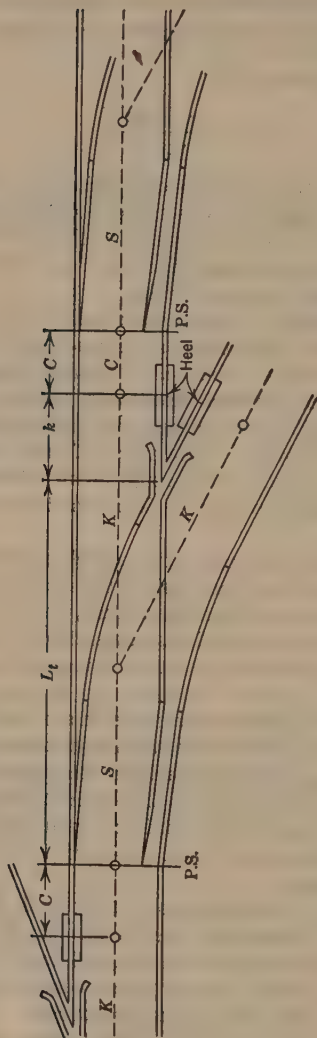


FIG. 101.

3. The minimum separation between turnouts (Fig. 101). A switch point cannot be placed exactly at the heel of a frog. There must be at least enough room beyond the heel for the joint bars and enough length of the next rail to give purchase for bending it. Sometimes the switch stands or the ties control. A minimum allowable value must be established.

In the following examples, the separations between adjacent turnouts and between curves and turnouts are designated by C with a subscript. Values of C between turnouts must never be less than the minimum as previously described. Values of C between turnouts and curves may be zero.

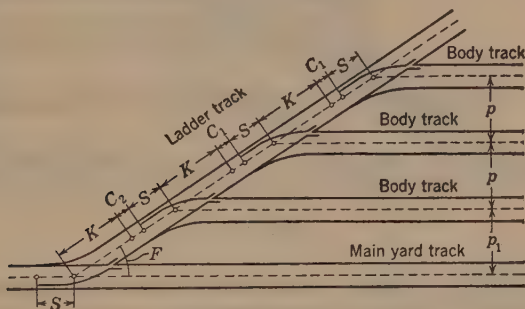


FIG. 102.

207. Computation of track positions in yards. Once the general arrangement of the track and the desired values of p , p_1 , r , and R have been established, a standard turnout is selected to be used generally throughout the yard. This choice determines F , K , S , and C min. The values of C are then computed for the yard as indicated in the examples. The order of computation used is designed to obtain the necessary values of p by adjusting the values of C on the ladder, and keeping the other C 's as small as possible. This procedure gives the maximum length of body tracks.

Example 1. Yard in which all body tracks are directly connected to the ladder without connecting curves (Fig. 102).

From the figure,

$$C_1 = \frac{p}{\sin F} - (K + S)$$

$$C_2 = \frac{p_1}{\sin F} - (K + S)$$

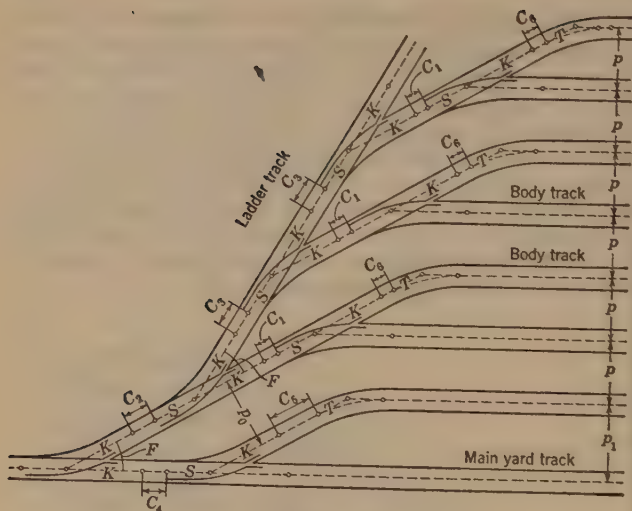


FIG. 103.

Example 2. Yard in which the body tracks are connected to the ladder in pairs without connecting curves (Fig. 103).

From the figure,

$$C_1 = \text{min.}$$

$$C_2 = \frac{p_1 + p}{\sin F} - 2(K + S) - C_1$$

$$C_3 = \frac{2p}{\sin 2F} - (K + S)$$

$$C_4 = \frac{p_0}{\sin F} - (K + S)$$

$$C_5 = \frac{p_1}{\sin F} - (K + T)$$

or

$$C_5 = 0 \quad \text{and} \quad R = T \cot \frac{F}{2}$$

$$C_6 = \frac{p}{\sin F} - (K + T)$$

or

$$C_6 = 0 \quad \text{and} \quad R = T \cot \frac{F}{2}$$

Example 3. Yard in which all body tracks are connected to the ladder by connecting curves (Fig. 104).

$$C_1 = \text{min.}$$

$$\sin \Delta = \frac{p}{K+C_1+S}$$

$$\alpha = \Delta - F$$

$$C_2 = 0$$

$$p_1 = (K+T) \sin F + (T+C_3+S) \sin \Delta + (K+T) \sin \alpha$$

Solving gives

$$C_3 = \frac{p_1 - (K+T)(\sin F + \sin \alpha)}{\sin \Delta} - (T+S)$$

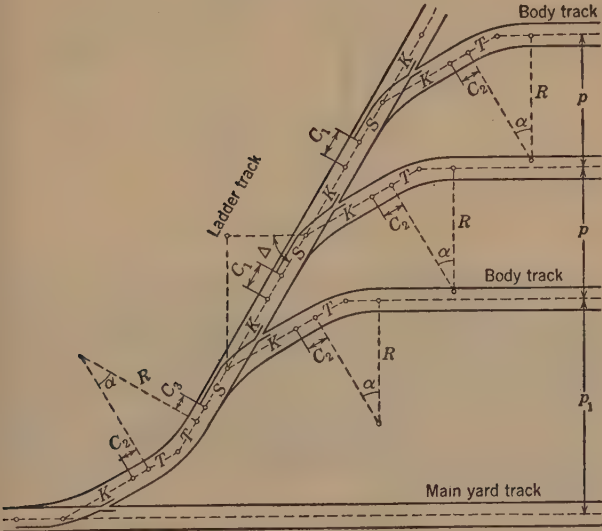


FIG. 104.

208. Coordinates. With the values of the C 's known, methods of staking out the yard are clear. Frequently, in complicated yards, the positions of points are reduced to coordinates which are used as an aid in staking out the yard.

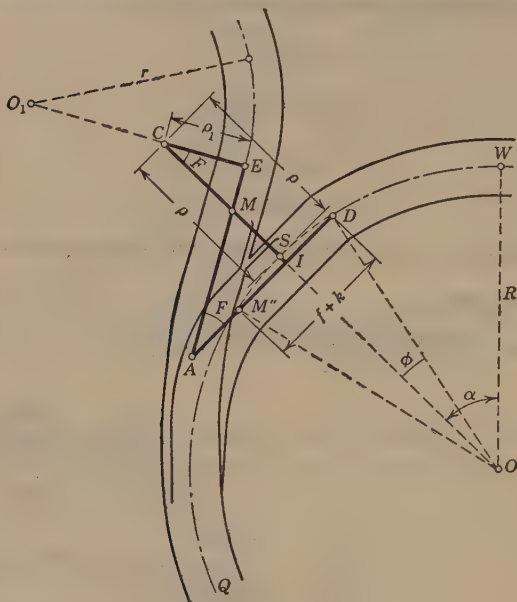


FIG. 105.

TURNOUTS FROM CURVED TRACKS

209. The location of frogs on curved tracks. When a turnout is placed in a curve which is already in place, it is common practice to place the frog so that it forms a chord of the curve. This is illustrated in Fig. 105. The center line of the original curve is represented by $QM''SDW$. The frog is placed so that the center line of one frog track $M''ID$ replaces the arc $M''SD$.

When the track arrangement is being designed, frogs are usually inserted in curves as previously described. How-

ever, a slightly better alignment can be obtained by breaking the curve into two parts connected by the main frog track to which both parts of the curve are tangent. This is illustrated in Fig. 106.

In both cases the side of the turnout which forms the main track between the toe of the frog and the heel of the switch

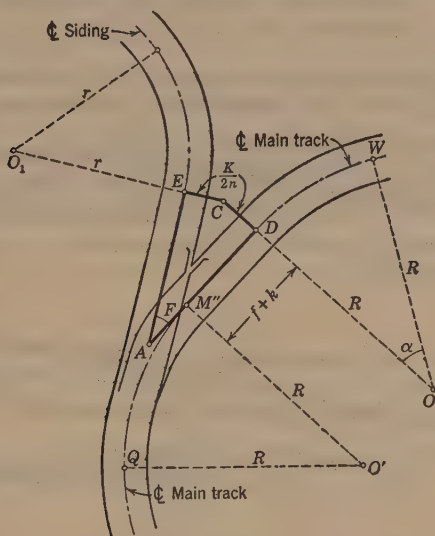


FIG. 106.

rails is centered on the main-curve center line. The remainder of the turnout is aligned by offsets from the curved main track. The values used for the offsets are the same as those computed for straight main track. See Fig. 107. This process changes the degree of the curve of the lead curve by the degree of the main curve as given below.

The approximate formula for the degree of curve of the lead curve is the following:

$$d' = d + D \quad (\text{approx.})$$

where d' = degree of lead curve (minus indicates curvature opposite in direction to its curvature on straight main track)

d = degree of lead curve computed for straight main track

D = degree of curve of main track, plus values being used when the main track curves in the same direction as the lead curve on straight main track and minus values for the opposite direction

The turnout arrangement shown in the middle diagram of Fig. 107 is known as a turnout with a **crotched frog**. Since

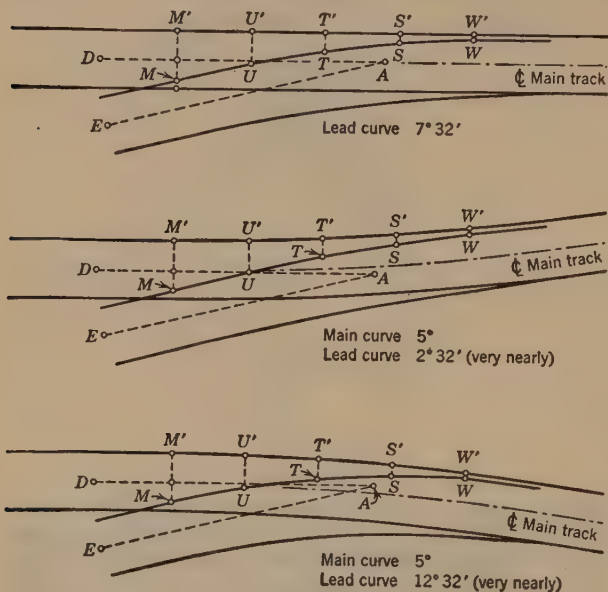


FIG. 107.

the radius of the lead curve is reduced, it is often possible to use a frog of a smaller number than if the main track side of the turnout were straight.

If the side track is a curve, it is made tangent to the frog track at the heel of the frog (E), as shown in Figs. 105 and

106. As mentioned in § 192, if space is available, the actual value of k should be increased up to 10 ft when the formulas are used. This results in a short tangent beyond the heel which improves alignment and reduces maintenance.

As in straight track, the problem is to find where the frog should be placed along the main track. The position of the frog is given by a computed central angle α measured from some known point W on the main curve to S in Fig. 105 or to D in Fig. 106. When S or D has been located, point A can be marked.

In the following paragraphs, the first method of locating a frog is used, as it is applicable whether or not the main curve is in place. It is a simple matter to convert the formulas thus derived to formulas for the second method.

210. To convert formulas for method I to formulas for method II. It may be seen from the discussion in the following paragraphs that, when the following substitutions are made in the formulas for method I, the formulas for method II result.

For ρ substitute $K/2n$

For ρ_1 substitute $-K/2n$

α computed with these substitutions extends to point D instead of to point S .

211. Data for method I. Certain data here called ρ_1 and ρ are used repeatedly. They are here derived (Fig. 105). Let O be the center of the main track curve $QM''IDW$ and O_1 be the center of the side track curve.

Construct O_1E perpendicular to AE and OC perpendicular to $M''D$ intersecting O_1E at C and AE at M .

From the figure,

$$ID = M''I = \frac{1}{2}(f+k) \quad \text{see § 183}$$

$$\sin \phi = \frac{ID}{R} = \frac{f+k}{2R}$$

$$SI = R \text{ vers } \phi$$

Hence SI .

$$AI = ng - f + \frac{1}{2}(f+k) = ng + \frac{1}{2}k - \frac{1}{2}f$$

$$MI = AI \tan F$$

Hence MI .

$$AM = \frac{AI}{\cos R}$$

$$ME = K - AM$$

$$CE = ME \cot F$$

Hence CE .

$$CM = \frac{ME}{\sin F}$$

Hence CM .

Let

$$\rho_1 = CE$$

and

$$\rho = CS = CM + MI - SI$$

Note. ρ_1 can be computed **once and for all** for any frog and, hence, constitute part of the turnout data. ρ_2 also can be computed once and for all if SI is assumed to be negligible. SI can never be greater than about 0.10, and, since it is always used with R , a large value, the assumption is always justifiable. When the turnout is toward the inside of the curve, the formula for ρ is the following:

$$\rho = CM + MI + SI$$

212. Turnout from curved main track to a siding (Figs. 108, 109, 110, and 111). Figures 108 and 109 represent a turnout to a siding outside the main track curve, and Figs. 110 and 111 represent a turnout to a siding inside the curve. In all figures QSV represents the curved main track of known radius R . HU represents the required position of the siding. H is the limit of curved track of the siding. V is the intersection of HU produced and the center line of the main track. Δ is the angle between HV and the tangent at V . r is the radius and Δ' the central angle of the siding curve.

Δ is always known from design or field measurement.

Make the construction shown in each figure.

Note. The cases occur under the same circumstances as for straight main track. See § 195 Note.

Case I. *Given: HV; to find r , Δ' , α .*

Outside, Figs. 108, 109:

In both figures,

$$B = (R + \rho) \cos F$$

$$N = (R + \rho) \sin F$$

$$P = R \cos \Delta$$

$$G = R \sin \Delta$$

$$M = HV$$

$$\overline{OO_1}^2 = (B - \rho_1 + r)^2 + N^2$$

$$\overline{OO_1}^2 = (r + P)^2 + (G + M)^2$$

Eliminating $\overline{OO_1}^2$ and solving for r gives

$$r = \frac{P^2 + (G + M)^2 - (B - \rho_1)^2 - N^2}{2(B - \rho_1 - P)} \quad (205)$$

From the figures,

$$\tan \beta = \frac{r + P}{G + M}$$

$$\tan \gamma = \frac{N}{B - \rho_1 + r}$$

$$\delta = F - \gamma$$

$$\theta = 90 - \beta + \delta$$

$$\alpha = \Delta - \theta$$

$$\Delta' = \Delta - \alpha - F$$

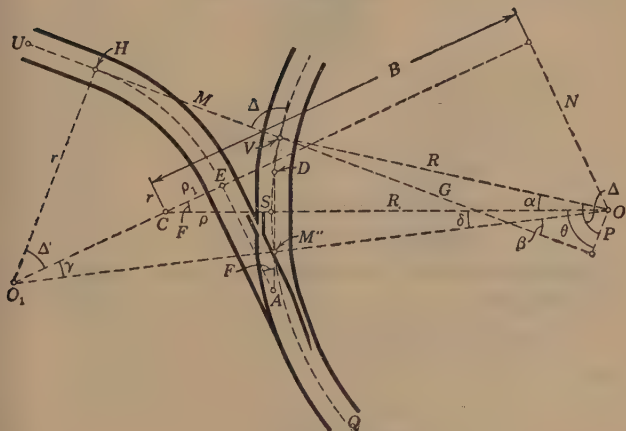


FIG. 108.

Case II. *Given: α ; to find Δ' , r , HV.*

Outside, Figs. 108, 109:

In both figures,

$$\Delta' = \Delta - \alpha - F$$

$$\theta = \Delta - \alpha$$

$$r + R \cos \Delta = (r - \rho_1) \cos \Delta' + (R + \rho) \cos \theta$$

Solving for r gives

$$r = \frac{R(\cos \theta - \cos \Delta) + \rho \cos \theta - \rho_1 \cos \Delta'}{\text{vers } \Delta'} \quad (206)$$

$$HV = (r - \rho_1) \sin \Delta' + (R + \rho) \sin \theta - R \sin \Delta \quad (207)$$

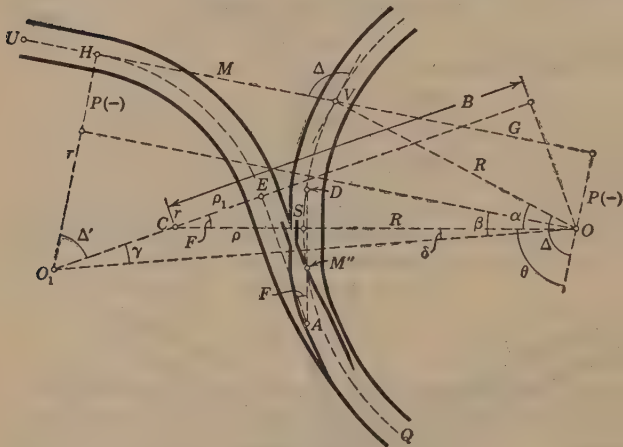


FIG. 109.

Case III. *Given: r ; to find α , HV, Δ' .*

Outside, Figs. 108, 109:

Solving triangle COO_1 by the tangent formula (Table XLII 26a) gives

$$\tan \frac{1}{2}(\gamma - \delta) = \frac{R + \rho - (r - \rho_1)}{R + \rho + (r - \rho_1)} \tan \frac{1}{2}(\gamma + \delta)$$

but

$$\gamma - \delta = F - \delta - \delta = F - 2\delta$$

$$\gamma + \delta = F$$

Substituting yields

$$\tan \frac{1}{2}(F-2\delta) = \frac{R+\rho-r+\rho_1}{R+\rho+r-\rho_1} \tan \frac{1}{2}F \quad (208)$$

Hence δ .

$$OO_1 = \frac{r-\rho_1}{\sin \delta} \sin F$$

Hence OO_1 .

$$\sin \beta = \frac{r+R \cos \Delta}{OO_1}$$

$$\alpha = \Delta - \delta - (90 - \beta)$$

$$HV = OO_1 \cos \beta - R \sin \Delta$$

$$\Delta' = \Delta - \alpha - F$$

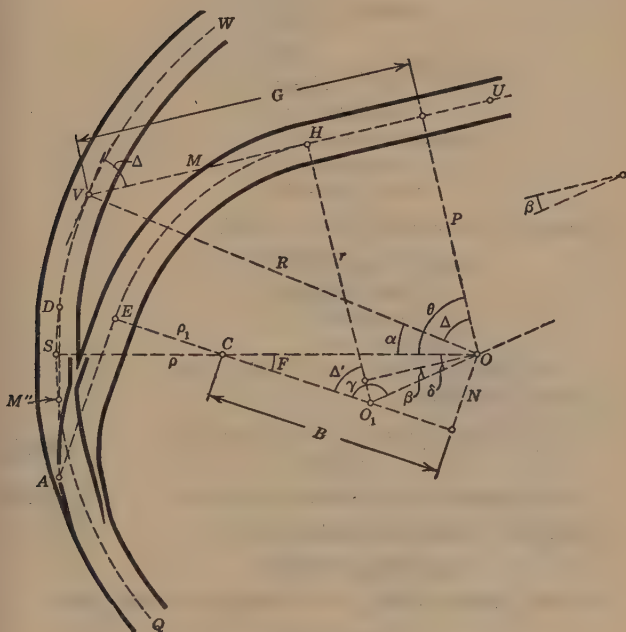


FIG. 110.

Case I. *Given: HV; to find r , Δ' , α*

Inside, Figs. 110, 111:

In both figures,

$$B = (R - \rho) \cos F$$

$$N = (R - \rho) \sin F$$

$$P = R \cos \Delta$$

$$G = R \sin \Delta$$

$$M = HV$$

$$\overline{OO_1}^2 = (B + \rho_1 - r)^2 + N^2$$

$$\overline{OO_1}^2 = (r - P)^2 + (G - M)^2$$

Eliminating $\overline{OO_1}^2$ and solving for r gives

$$r = \frac{P^2 + (G - M)^2 - (B + \rho_1)^2 - N^2}{2(P - B - \rho_1)} \quad (205A)$$

From the figures,

$$\tan \beta = \frac{r - P}{G - M}$$

$$\tan (180 - \gamma) = \frac{N}{B + \rho_1 - r}$$

$$\delta = (180 - \gamma) - F$$

$$\alpha + \Delta + \delta = 90 + \beta$$

$$\alpha = 90 + \beta - \Delta - \delta$$

$$\Delta' = \Delta + \alpha - F$$

Case II. *Given: α ; to find Δ' , r , HV.*

Inside, Figs. 110, 111:

In both figures,

$$\Delta' = \Delta + \alpha - F$$

$$\theta = \Delta + \alpha$$

$$r - R \cos \Delta = (r - \rho_1) \cos \Delta' - (R - \rho) \cos \theta$$

Solving for r gives

$$r = \frac{R(\cos \Delta - \cos \theta) + \rho \cos \theta - \rho_1 \cos \Delta'}{\text{vers } \Delta'} \quad (206A)$$

$$HV = R \sin \Delta - (R - \rho) \sin \theta + (r - \rho_1) \sin \Delta' \quad (207A)$$

Case III. *Given: r ; to find α , HV, Δ' .*

Inside, Figs. 110, 111:

Solving triangle COO_1 by the tangent formula gives

$$\tan \frac{1}{2}(\gamma - \delta) = \frac{R - \rho - (r - \rho_1)}{R - \rho + (r - \rho_1)} \tan \frac{1}{2}(\gamma + \delta)$$

but

$$\frac{\gamma - \delta}{2} = \frac{180 - (F + 2\delta)}{2} = 90 - \frac{1}{2}(F + 2\delta)$$

$$\gamma + \delta = 180 - F$$

Substituting yields

$$\cot \frac{1}{2}(F + 2\delta) = \frac{R - \rho - r + \rho_1}{R - \rho + r - \rho_1} \cot \frac{1}{2}F \quad (208A)$$

Hence δ .

$$OO_1 = \frac{r - \rho_1}{\sin \delta} \sin F$$

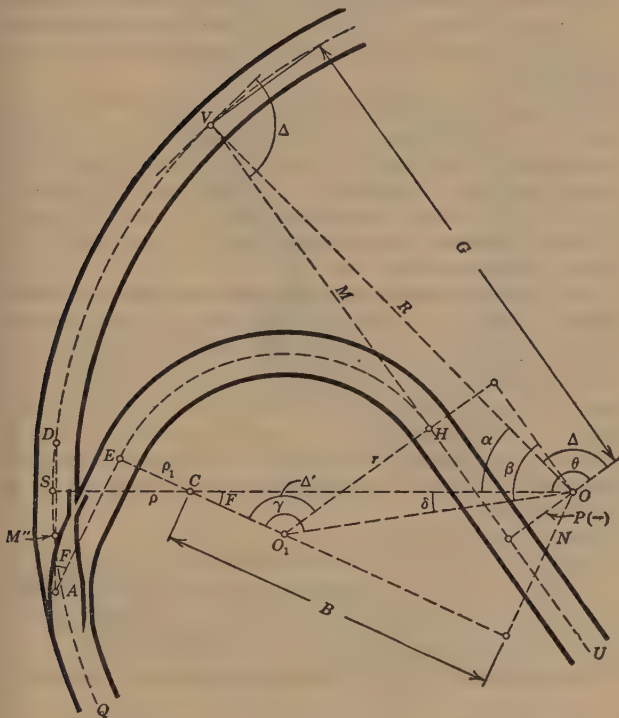


FIG. 111.

Hence OO_1 .

$$\sin \beta' = \frac{r - R \cos \Delta}{OO_1}$$

$$\alpha = \beta + 90 - \Delta - \delta$$

$$HV = R \sin \Delta - OO_1 \cos \beta$$

$$\Delta' = \Delta + \alpha - F$$

Field procedure when the main track is in place. From the value of α compute the center-line distance VS and mark the center-line point S . By measuring half the sum of $k+f$ both directions from S , mark the points D and M'' . The difference between the arc and the chord is negligible. Set A on the line DM'' at the distance K from D . At A turn off the angle F . Measure K from A , and set E . With these points the frog position can be marked, and the tangent of the turnout is established.

The tangent AE should be run to intersect HV at a P.I., and Δ' and the two tangents, E to P.I., and H to P.I., should be measured. They should be theoretically both equal to the value $r \tan \frac{1}{2}\Delta'$. Choosing the smallest for T , compute $r = T \cot \frac{1}{2}\Delta'$. Select a convenient degree of a curve of equal or slightly smaller radius, establish the P.T. and the P.C., and run the curve in the usual way.

213. Turnout from a curved main track to a parallel siding. Three cases exist as illustrated by three figures (Figs. 112, 113, 114). In all three figures O is the center of the main track curve and the siding, R is the radius of the main track curve, p is the required center-line distance between tracks, O_1 is the center of the connecting curve of radius r extending from point E at the heel of the frog to G a point of tangency with the siding, having the central angle Δ' . α is the angle GOS .

Given: R, p ; *to find* r, α, Δ' .

Case I. *Siding outside the main track curve* (Fig. 112).

Produce OO_1 to U . It must pass through G by hypothesis.

With O_1 as a center and the radius $r + \rho_1$ describe an arc intersecting OS produced at C and OG produced at U .

Solving triangle UCO by the tangent formula, we have

$$\tan \frac{1}{2}(UCO + CUO) = \tan \frac{1}{2}(UCO - CUO) \frac{UO + CO}{UO - CO}$$

But

$$UCO + CUO = 180 - \alpha$$

$$\frac{1}{2}(UCO + CUO) = 90 - \frac{1}{2}\alpha$$

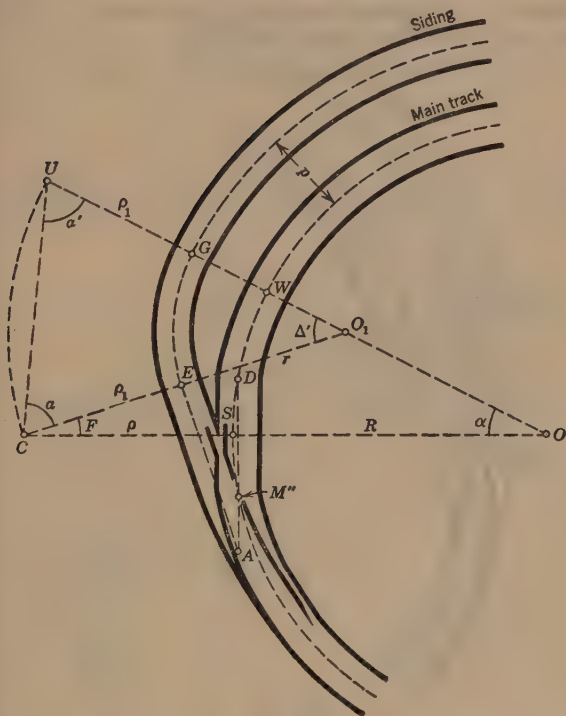


FIG. 112.

And, since triangle O_1CU is isosceles, having equal base angles a and a' ,

$$UCO - CUO = F$$

Substituting gives

$$\cot \frac{1}{2}\alpha = \tan \frac{1}{2}F \frac{2R + p + \rho + \rho_1}{\rho_1 + p - \rho} \quad (209)$$

And

$$\Delta' = F + \alpha$$

Solving triangle COO_1 by the sine formula, gives

$$r + \rho = \frac{R + \rho}{\sin \Delta'} \sin \alpha$$

Case II. *Siding inside main track curve with a connecting curve having the reverse direction (Fig. 113).*

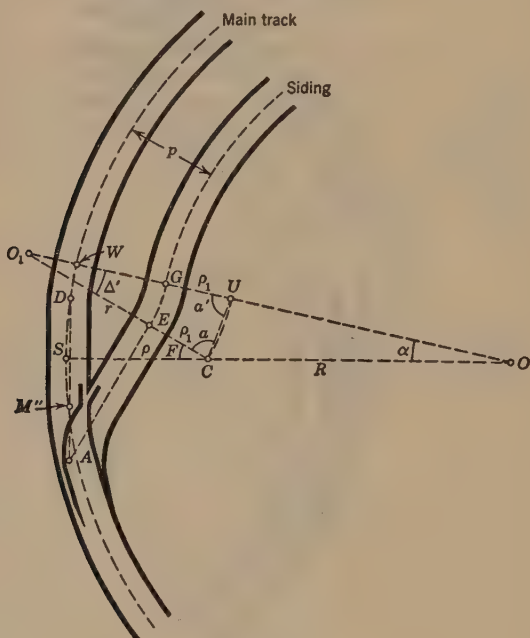


FIG. 113.

In a manner similar to case I:

Solving triangle UCO by the tangent formula, gives

$$\tan \frac{1}{2}(CUO + UCO) = \tan \frac{1}{2}(CUO - UCO) \frac{CO + UO}{CO - UO}$$

But

$$\frac{1}{2}(CUO + UCO) = 90 - \frac{1}{2}\alpha$$

$$CUO - UCO = 180 - a - (180 - F - a)$$

$$\frac{1}{2}(CUO - UCO) = \frac{1}{2}F$$

Substituting gives

$$\cot \frac{1}{2}\alpha = \tan \frac{1}{2}F \frac{2R - p - \rho - \rho_1}{p - \rho + \rho_1} \quad (209A)$$

and

$$\Delta' = F - \alpha$$

Solving triangle COO_1 by the sine formula gives

$$r + \rho_1 = \frac{R - \rho}{\sin \Delta'} \sin \alpha$$

Case III. *Siding inside main track curve with a connecting curve having the same direction (Fig. 114).*

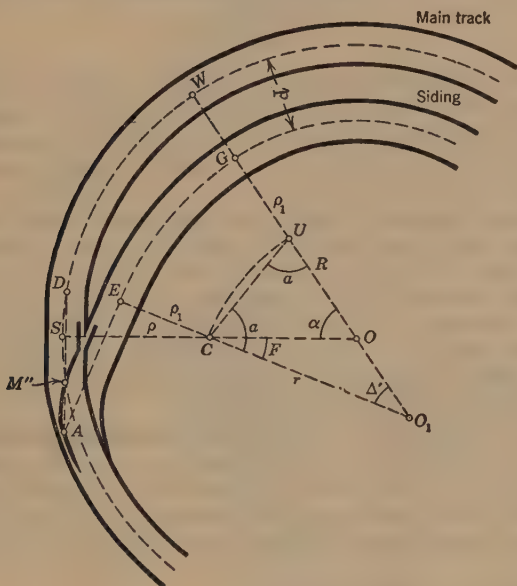


FIG. 114.

In a manner similar to case I:

Solving triangle UCO by the tangent formula, gives

$$\tan \frac{1}{2}(CUO + UCO) = \tan \frac{1}{2}(CUO - UCO) \frac{CO + UO}{CO - UO}$$

But

$$\frac{1}{2}(CUO + UCO) = 90 - \frac{1}{2}\alpha$$

$$CUO - UCO = a - (a - F)$$

$$\frac{1}{2}(CUO - UCO) = \frac{1}{2}F$$

Substituting gives

$$\cot \frac{1}{2}\alpha = \tan \frac{1}{2}F \frac{2R - p - \rho - \rho_1}{p - \rho + \rho_1} \quad (209B)$$

$$\Delta' = \alpha - F$$

Solving the triangle COO_1 by the sine formula, we have

$$r - \rho_1 = \frac{R - \rho}{\sin \Delta'} \sin \alpha$$

Field procedure when the main track is in place. Choose the point W on the main track where it is desired to depart from the standard center-line separation p . Using α , proceed as in § 212 to set points S , D , M'' , A , and E . Set G from W , and run the curve from E to G .

Alternate method. When the curvature is not sharp, it is common practice to avoid all computation by using the plusses and offsets developed for a turnout from a straight track to a parallel side track (§ 205). All plusses are measured along the curved main track, and the offsets are measured radially from it. The degrees of curvature can be estimated by applying the degree of curvature of the main track to the degree of curvature that occurs with straight track.

214. Cross-over by a simple curve connecting parallel curved tracks (Fig. 115). *In the figure O is the center of the parallel tracks, R the radius of the inside track, p the distance between track center lines, O_1 the center of the connecting curve of radius r having the central angle Δ' , and α is the angle SOS' .*

Given: R , p ; to find r , α , Δ' .

With O_1 as a center and the radius $r + \rho_1$, describe an arc intersecting OS produced at C and O_1E' produced at U .

Solving the triangle $UC'O$ by the tangent formula gives

$$\tan \frac{1}{2}(\theta - \phi) = \tan \frac{1}{2}(\theta + \phi) \frac{C'O - C'U}{C'O + C'U}$$

Solving the triangle UCO by the tangent formula gives

$$\tan \frac{1}{2}(OCU + OUC) = \tan \frac{1}{2}(OCU - OUC) \frac{OU + OC}{OU - OC}$$

But

$$\frac{1}{2}(OCU + OUC) = 90 - \frac{1}{2}(\alpha - \phi)$$

$$OCU - OUC = F + a - (a - \theta)$$

$$\frac{1}{2}(OCU - OUC) = \frac{1}{2}(F + \theta)$$

OU = value previously computed above, $OC = R + \rho$

Substituting, gives

$$\cot \frac{1}{2}(\alpha - \phi) = \tan \frac{1}{2}(F + \theta) \frac{OU + R + \rho}{OU - (R + \rho)}$$

Hence α , and

$$\Delta' = \alpha + F - F'$$

$$a = \frac{1}{2}(180 - \Delta')$$

Hence a .

Solving the triangle UCO by the sine formula, we have

$$UC = \frac{OU}{\sin (F + a)} \sin (\alpha - \phi)$$

Hence UC .

Then,

$$r + \rho_1 = \frac{\frac{1}{2}UC}{\sin \frac{1}{2}\Delta'}$$

Hence r .

215. Cross-over by a reversed curve connecting parallel curved tracks (Fig. 116). In the figure, O is the center of parallel tracks, R the radius of the inside track, p the distance between track center lines, O_1 and O_2 are the centers of the reversed curve of radii r and r' , respectively, and have the central angles Δ and Δ' , respectively. α is the angle SOS' .

Given: R, p, r, r' ; *to find* a and Δ, Δ' .

Step 1. Solving the triangle $O_2C'O$ by the tangent formula gives

$$\tan \frac{1}{2}(C'O_2O - C'OO_2) = \tan \frac{1}{2}(C'O_2O + C'OO_2) \frac{C'O - C'O_2}{C'O + C'O_2}$$

But

$$\tan \frac{1}{2}(C'O_2O + C'OO_2) = \tan \frac{1}{2}(180 - F') = \cot \frac{1}{2}F'$$

$$C'O = R + p - \rho', \quad C'O_2 = r' - \rho_1'$$

Hence $C'O_2O$ and $C'OO_2$.

Solving the triangle $O_2C'O$ by the sine formula gives

$$OO_2 = \frac{R+p-\rho'}{\sin C'O_2O} \sin F'$$

Hence OO_2 .

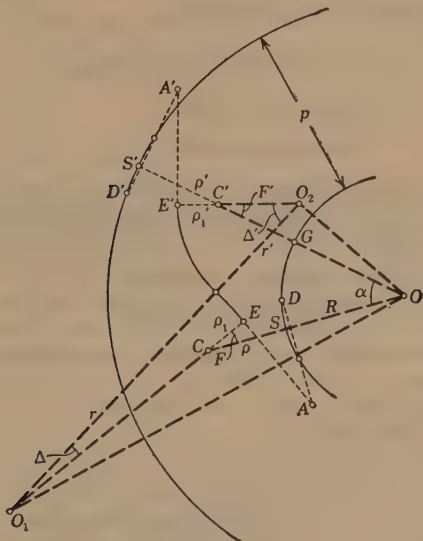


FIG. 116.

Step 2. Solving the triangle O_1CO by the tangent formula gives

$$\tan \frac{1}{2}(COO_1 - CO_1O) = \tan \frac{1}{2}(COO_1 + CO_1O) \frac{CO_1 - CO}{CO_1 + CO}$$

But

$$\tan \frac{1}{2}(COO_1 + CO_1O) = \tan \frac{1}{2}F$$

$$CO_1 = r - \rho_1 \quad CO = R + \rho$$

Hence COO_1 and CO_1O .

Solving the triangle O_1CO by the sine formula gives

$$OO_1 = \frac{r - \rho_1}{\sin COO_1} \sin F$$

Hence OO_1 .

Step 3. Solve triangle OO_1O_2 of which the three sides are known, namely:

OO_1 and OO_2 were computed in steps 1 and 2.

$$O_1O_2 = r + r'$$

Use formulas 30-33, Table XLII.

Then,

$$\alpha = O_2OO_1 - O_2OC' - COO_1$$

$$\Delta = O_2O_1O - CO_1O$$

$$\Delta' = \Delta + F + \alpha - F'$$

216. Field procedure for laying out a cross-over between two parallel curved tracks when the tracks are in place. Choose a position for the frog on one of the tracks. Set S in accordance with the turnout data. Set G by measuring along the track center line a distance equivalent to the central angle α . S' can then be set. With S and S' established, the complete turnout can be located. Run the curve (simple or reversed, as required) from E to E' in the usual way.

Alternate method. When the curvature is not sharp, it is common practice to avoid all computation by using the plusses and offsets developed for cross-overs between parallel straight track (§ 198). All plusses are measured along one of the curved main tracks, and the offsets are measured radially from it. The degrees of curvature can be estimated by applying the degree of curvature of the main track to the degree of curvature that occurs with straight track.

Note. Cross-overs on curves should be avoided if possible. They are difficult to build and maintain, they jolt trains that run over them, and it is necessary to superelevate both tracks to the same plane to install them. The latter may require raising the outside track as much as 18 in. to avoid producing a sag in the profile of the inside track.

217. Connecting track that reverses direction (Fig. 117). AV and $A'V$ represent the center lines of two straight tracks intersecting at V . They are connected by two different turnouts and a simple curve of radius r .

From A' drop a perpendicular $A'J$ to the line AV . Let t represent the distance AV , t' the distance $A'V$, and Δ the angle of intersection between AV and VA' .

From the figure, by projection on the line $A'J$

$$t' \sin \Delta = K' \cos [F' - (\Delta - 90)] + r[\text{vers } (\Delta - F') - \text{vers } F] + K \sin F \quad (210)$$

and, by projection on a line perpendicular to $A'V$,

$$t \sin \Delta = K \cos [F - (\Delta - 90)] + r[\text{vers } (\Delta - F) - \text{vers } F'] + K' \sin F' \quad (210A)$$

Case I. *Given:* r ; *to find* t , t'

Use equations 210 and 210A.

Case II. *Given:* t' ; *to find* r and t .

Solve equation 210 for r .

$$r = \frac{t' \sin \Delta - K' \cos [F' - (\Delta - 90)] - K \sin F}{\text{vers } (\Delta - F') - \text{vers } F}$$

Use equation 210A.

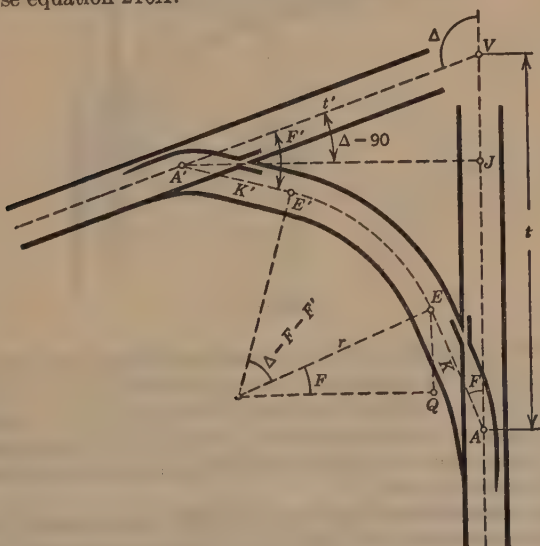


FIG. 117.

218. Wyes. A wye is a track arrangement somewhat in the form of a "Y," requiring three turnouts, which is used to turn an engine around. See Fig. 118. Two turnouts are located on the main track, and a third turnout connects with both. Usually the location of the third turnout is controlled

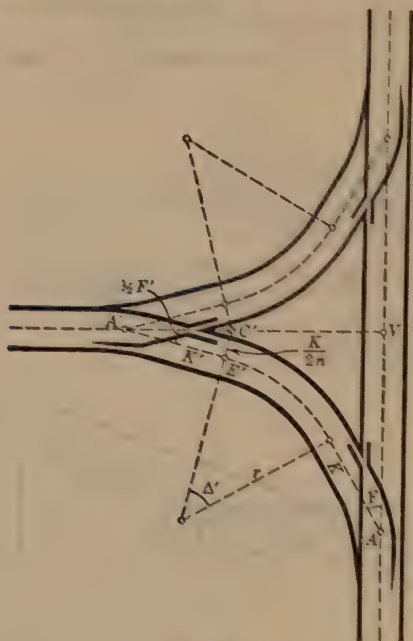


FIG. 118.

by the topography. When its location has been established, the problem of connecting the two branches to the main track resolves itself into connecting two sidings to the main track as covered in §§ 195 and 212. When the topography does not control, the wye can be made symmetrical and thus utilize a minimum of track.

219. Symmetrical wye on straight main track (Fig. 118). In the figure, $A'V$ represents the line of symmetry. The crotched frog should be of a smaller number than the two

frogs on the main track. Δ' is the central angle of the connecting curve of radius r , and the angle at V is 90° .

Given r : to find $A'V$ and AV .

From the figure,

$$\Delta' = 90 - F - \frac{1}{2}F'$$

By projection on $A'V$,

$$A'V = K' \cos \frac{1}{2}F' + r[\text{vers}(\Delta' + F) - \text{vers} F] + K \sin F \quad (211)$$

By projection on AV ,

$$AV = K \sin \frac{1}{2}F' + r[\sin(\Delta' + F) - \sin F] + K \cos F \quad (211A)$$

220. Symmetrical wye on curved main track (Fig. 119).

In the figure, $A'O$ represents the line of symmetry. Δ' is the central angle of connecting curve of the radius r . R is the radius of the main track.

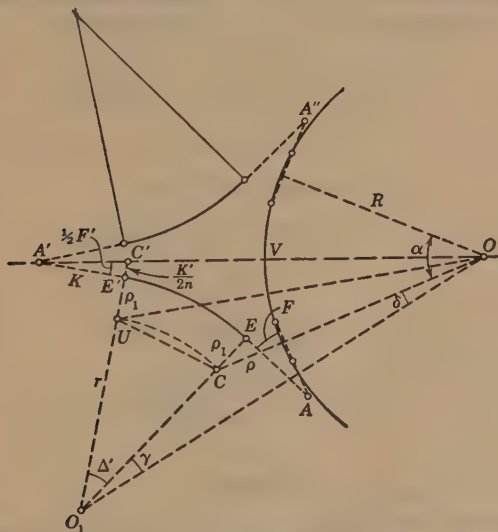


FIG. 119.

Given: r ; to find $A'V$, α , Δ' .

With O_1 as a center and $r - \rho_1$ as a radius, describe an arc intersecting O_1E at C and O_1E' at U .

Solving triangle O_1CO by the tangent formula gives

$$\tan \frac{1}{2}(\gamma - \delta) = \frac{R + p - (r - \rho_1)}{R + p + (r - \rho_1)} = \tan \frac{1}{2}(\gamma + \delta)$$

but

$$\gamma - \delta = F - \delta - \delta = F - 2\delta$$

$$\gamma + \delta = F$$

Substituting, gives

$$\tan \frac{1}{2}(F - 2\delta) = \frac{R + p - r + \rho_1}{R + p + r - \rho_1} \tan \frac{1}{2}F \quad (212)$$

Hence δ .

Solving triangle O_1CO by the sine formula gives

$$OO_1 = \frac{r - \rho_1}{\sin \delta} \sin F$$

Hence OO_1 .

Solving triangle $O_1C'O$ by the sine formula yields

$$\sin C'OO_1 = \frac{\sin (90 - \frac{1}{2}F')}{OO_1} \left(r + \frac{K}{2n} \right)$$

but

$$\frac{1}{2}\alpha = C'OO_1 - \delta$$

$$\Delta' + \gamma = 90 - \frac{1}{2}F' - C'OO_1$$

$$\Delta' = 90 - \frac{1}{2}F' - \gamma - C'OO_1$$

Also,

$$C'O = \frac{r + \frac{K'}{2n}}{\sin C'OO_1} \sin (\Delta' + \gamma)$$

$$A'V = C'O + \frac{K'}{\cos \frac{1}{2}F'} - R$$

CROSSINGS

221. When two tracks cross, four frogs are necessary. Both tracks may be straight, one may be straight and the other curved, or both may be curved. With both tracks straight, two frog angles are supplements of the other two. In this case, right triangles are solved, and no special formulas need be derived.

In any case, it is only by chance that standard frogs can be used. When either or both tracks are curved, the frogs are often built with curved rails. It is common practice to assume that the rails are curved when computing crossings on curved track.

Given: a straight track of gauge g crossing a curved track with radius R and gauge g' and the angle between the center lines; to find the frog angles and the distances between the frog points (Fig. 120).

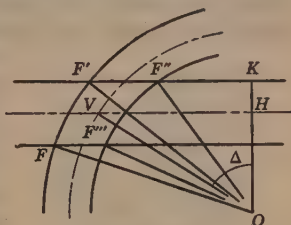


FIG. 120.

From O , the center of the main track, draw the lines OF , OF' , OF'' , and OF''' ; also OH perpendicular to VH .

Let g and g' be the gauges of the straight and curved tracks;

$$OV = R \quad \text{and} \quad \text{angle } HVO = 90^\circ - \Delta$$

Then,

$$OH = OV \sin (90^\circ - \Delta) = R \cos \Delta$$

$$\cos F = \frac{OH - \frac{1}{2}g}{R + \frac{1}{2}g'} \quad (213)$$

$$\cos F' = \frac{OH + \frac{1}{2}g}{R + \frac{1}{2}g'} \quad (213A)$$

$$\cos F'' = \frac{OH + \frac{1}{2}g}{R - \frac{1}{2}g'} \quad (213B)$$

$$\cos F''' = \frac{OH - \frac{1}{2}g}{R - \frac{1}{2}g'} \quad (213C)$$

$$F'F'' = F'K - F''K$$

$$= (R + \frac{1}{2}g') \sin F' - (R - \frac{1}{2}g') \sin F'' \quad (214)$$

A similar equation may be found for FF''' .

$$FF' = (R + \frac{1}{2}g') \text{arc } (F - F') \quad (215)$$

in which "arc" is regarded as a function of the angle, to radius unity, and to be found in Table XXA.

So also,

$$F''F''' = (R - \frac{1}{2}g') \text{ arc } (F''' - F'') \quad (216)$$

It is to be noted that these lengths are between the theoretical frog points. In constructing the crossing, allowance

should be made for the flange-ways.

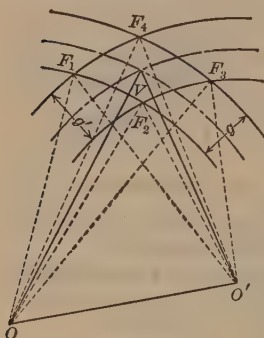


FIG. 121.

222. Given: the radii R and R' of two curved tracks of gauges g and g' which cross at V at an angle Δ ; to find the frog angles and the lengths of the curved rails (Fig. 121).

Let $OV = R$, $O'V = R'$, and $OVO' = \Delta$.

Solve the triangle OVO' for OO' having given two sides and an included angle. The triangle OF_1O' may be solved for F_1 , and the angles F_1OO' and $F_1O'O$, having given $OF_1 = R - \frac{1}{2}g$, $O'F_1 = R' + \frac{1}{2}g'$, and OO' .

Similarly with the triangles OF_2O' , OF_3O' and OF_4O' .

Then, the angle,

$$F_1OF_2 = F_1OO' - F_2OO'$$

and

$$F_1F_2 = (R - \frac{1}{2}g) \text{ arc } F_1OF_2 \quad (217)$$

The other three lengths may be calculated in a similar way.

223. At the crossing of two tracks, traffic may be switched from one track to the other by a combination crossing called a **slip switch**. The switches and lead rails are entirely included between the main frogs. A great saving of room is gained over other forms of connections, but, on account of the small distance between the extreme frog points, the angle between the tracks must be slight.

Given: the angle at which two straight tracks cross and the data for the switches and frogs; to find the distances along the curved rail between frog points for a slip switch crossing and the radius of the curve connecting the heels of the switches (Figs. 122 and 123).

Let $AK = BJ =$ the length of the switch rail l , and DK and $LJ =$ the distance gauge to gauge at heel of switch h .

The distances F_1A and F_3B are governed by the clearance necessary from frog point to switch point as mentioned in § 206.

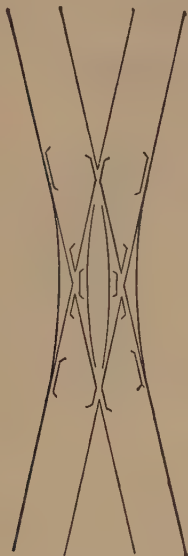


FIG. 122.

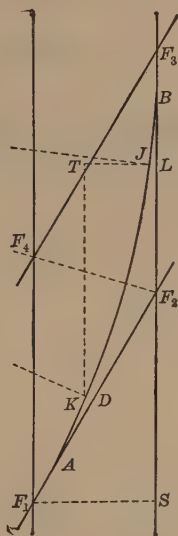


FIG. 123.

The distances between successive theoretical frog points are all the same and are expressed by

$$F_1F_2 = F_2F_3 = F_3F_4 = F_4F_1 = \frac{g}{\sin F} \quad (218)$$

At the point F_2 and F_4 the theoretical and actual points coincide.

The direct distance between theoretical frog points F_1 and F_3 is

$$F_1F_3 = \frac{g}{\sin \frac{1}{2}F} \quad (219)$$

Similar to the solution given in § 183, two expressions for JT may be found which are

$$JT = g - h - R_1 A \sin F - l \sin (F - S)$$

and

$$JT = (R + \frac{1}{2}g) \cos S - (R + \frac{1}{2}g) \cos (F - S)$$

Equating these two values and solving for R , we obtain

$$R + \frac{1}{2}g = \frac{g - h - F_1 A \sin F - l \sin (F - S)}{\cos S - \cos (F - S)} \quad (220)$$

The length of the outer curve is

$$KJ = (R + \frac{1}{2}g) \text{arc } (F - 2S)$$

CHAPTER IX

THE SPIRAL CURVES

THE SEARLES SPIRAL

224. In the early years of railroad building it was considered quite sufficient that the curves should be circles and the straight lines truly tangent to the curves. But, as train speeds were increased, it became necessary to introduce a curve of variable radius between the tangent and circle for two reasons: first, to avoid the lateral shock produced at the tangent point either on entering or leaving the circle, and second, to permit an elevation of the outer rail which should be everywhere proportional to the degree of curve. See Chapter XVI for derivation of formula for elevation of the outer rail.

A car running at high speed on a straight track is suddenly forced aside and takes up a circular motion on striking a curve, and on the curve the car body continues to revolve horizontally, like a huge bar suspended at its center of gravity, until its revolution is suddenly arrested by another piece of straight track. In either case a shock is produced deleterious both to track and rolling stock. By introducing a short curve of variable radius, that is, a spiral, the transition is made easy and almost insensible.

Without proper spirals, track alignment deteriorates rapidly. The increased impact of traffic not only moves the track out of alignment but also creates a condition that further increases impact. Accordingly, spirals reduce track maintenance costs and today are used even on lines devoted exclusively to freight.

The spiral curve here described fully meets the foregoing requirements. It not only blends with the tangent at one end and with the circle at the other, but it also affords sufficient distance between the two for the gradual elevation of the outer rail. In shape it conforms very nearly to the cubic

parabola with the advantage of requiring less track near the tangent point. The first radius is amply long without being infinite. The spiral curve is constructed on a series of equal chords, and the angle subtended by the first chord is made the common difference for the angles subtended by the succeeding chords. It is a multicomponent curve in which the degree of curve progresses in arithmetical ratio from chord to chord.

225. Let the chord length be 100 ft and the central angles be 10', 20', 30', etc., subtended by these chords. There are what might be called three elements of the spiral:

(a) The angles subtended by each chord; these are 10', 20', 30', 40', 50', etc.

(b) The total spiral angle up to any specified point; these are 10', 30', 1° 0', 1° 40', 2° 30' for points 1 to 5, inclusive.

(c) The inclination of any chord to a line parallel to the main tangent. This is equal to half the angle the particular chord subtends added to the total preceding central angle. The correctness of this statement may be seen by drawing a common tangent to the curve at the point in question. These inclinations are 5', 20', 45', 1° 20' and 2° 05' for points 1 to 5, inclusive. In other words the angles of inclination vary as the square of the chord point number from the beginning of the spiral.

Thus, we obtain the first four columns of Table XXXIV.

If the tangent is taken as a meridian, the inclination of a chord becomes its bearing, from which its latitude, or $100 \cos \text{incl.}$, and departure, or $100 \sin \text{incl.}$, may be quickly computed. If the tangent point S is taken as an origin, and x and y are called the *coordinates of the several chord points*, the continuous summation of latitudes gives values of y and of departures gives values of x . These are all given in Table XXXIV.

226. Spiral deflections (Fig. 124). With the transit at S the deflection i from the tangent to any other chord point is found by the formula:

$$\tan i = \frac{x}{y} \quad (221)$$

With the transit at any chord point n , to find the deflection from the local tangent through n to any other chord point: observe, first, that for the adjacent point, whether forward or backward,

the deflection is one-half the angle subtended by the adjacent chord; thus, Fig. 125, with transit at point 3 the deflection to 4 is 20', and to point 2 it is 15'. For more distant forward points, draw long chords to them from n , find the angle a that such long chord makes with the main tangent, and deduct the

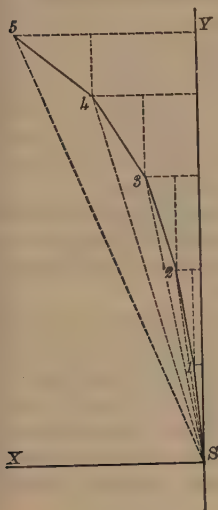


FIG. 124.

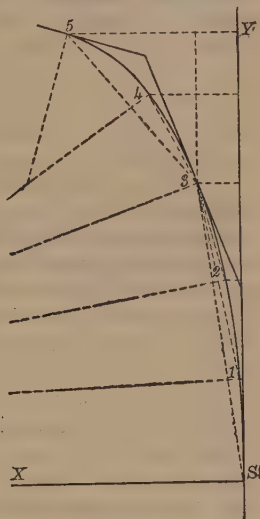


FIG. 125.

angle between the main and local tangents; the difference is the value of i required. The angle a is found from

$$\tan a = \frac{x - x'}{y - y'} \quad (222)$$

in which x, y are the coordinates of the point observed and x', y' of the position of transit. And

$$i = a - s \quad (223)$$

Thus, with transit at 3 we have, for point 5,

$$\tan a = \frac{7.998 - 2.036}{499.896 - 299.989} = \frac{5.962}{199.907} = 0.029825$$

and

$$a = 1^\circ 42' 30''$$

Since, for 3,

$$s = 1^\circ$$

$$\lambda = 0^\circ 42' 30''$$

The angle subtended by a long chord is equal to the difference of the values of s for the extremities of the chord; it is also equal to the sum of the deflections made at either end of the long chord to find the other. Hence, knowing the central angle and forward deflection along any long chord, we find by subtraction the backward deflection along the same chord. Thus, with transit at 3 to find 1, since $s' - s = 50'$ and the forward deflection from 1 is $22' 30''$, the difference, or $27' 30'' = i$ = the deflection required.

In this manner the entire Deflection Table XXXV has been calculated, and, since the spiral is invariable in form, all its angles are constant, and the deflections given are available in every case that can occur in practice.

227. To adapt the spiral to practical requirements *it is only necessary to draw the figure to a different scale.* All its dimensions remain *proportional* to each other, including the radii of the arcs composing the spiral. The chord length assumed at 100 ft is now to be given smaller values ranging from 10 to 50 ft, and all other parts are calculated accordingly, varying directly as the chord length, while the degree of curve varies inversely, or nearly so.

Table XXXVI furnishes exact values of the degree of curve D_s , length of spiral nc , and values of the coordinates at each point for a variety of chord lengths. Among these spirals may always be found one or more that will be well adapted to the case in hand.

In selecting a spiral, *first* consult the diagram shown in Table XXXIII having the velocity and degree of curve given. From this take the minimum allowable length of spiral. *Second*, from Table XXXVI select a spiral such that the length is equal to or more than the minimum allowable, and the degree of which on the $(n+1)$ chord will equal, as nearly as may be, the required degree of curve. The number of chords to be taken will be n and not $(n+1)$.

228. To find the spiral long chord SL and the spiral tangents SE , LE , (Fig. 126).

Let L be the terminal point of the spiral, x, y the coordinates of L , i the deflection ESL , and s the central angle YEL . Then, from the figure,

$$SL = \frac{y}{\cos i} \quad \text{or} \quad SL = \frac{x}{\sin i} \quad (224)$$

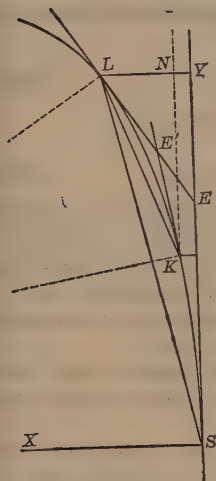


FIG. 126.

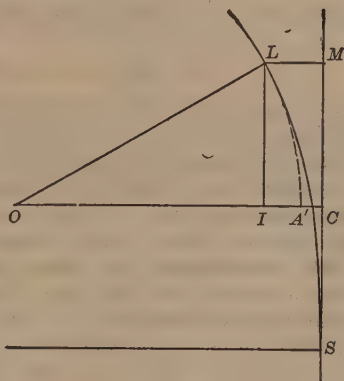


FIG. 127.

To find the spiral tangents, in the triangle LEY ,

$$LE = \frac{x}{\sin s} \quad \text{and} \quad SE = y - x \cot s \quad (225)$$

To find any other spiral long chord, as KL , and the spiral tangents, KE' , LE' : let s' be the central angle for K , and i' the deflection at K for KL . Then, from the figure,

$$KL = \frac{KN}{\cos LKN} = \frac{y - y'}{\cos (s' + i')} \quad (226)$$

Take values of y and y' from Table XXXVI; values of s' and i' from Table XXXV.

In the triangle KLE' , since $KE'E = (s - s')$,

$$LE' = \frac{KL \sin i'}{\sin (s - s')}; \quad KE' = \frac{KL \sin i}{\sin (s - s')} \quad (227)$$

Values of spiral long chords and tangents appear in Table XXXVIII.

229. With a spiral terminating at L , Fig. 127, if the circular arc on the following chord length were produced backward from L through the angle s , it would terminate at A' in a line parallel to the main tangent, the perpendicular distance p , between the two being $LM - IA'$, or

$$p = x - R' \text{ vers } s \quad (228)$$

in which R' is the radius of the spiral arc $(n+1)$.

Also,

$$q = SM - LI = y - R' \sin s \quad (229)$$

We thus have q and p as the *coordinates of the point A'* which are often convenient either in the field or the office. Values of p appear in Table XXXVIII. *But, if the radius of the curve beyond L differs from that of the spiral arc $(n+1)$, these values of p will not apply to it and must be computed. (Compare p in Tables XXXVIII and XXXIX.)*

230. Combination of curve and spiral (Fig. 128).

Given: a circular curve with equal spirals joining two tangents; to find the tangent distance, $T_s = VS$.

Let SL be one spiral and LH one half of the curve with its center at O . Join OL and OV , and through L draw GI parallel to the tangent, and GN , LM perpendicular to it. Then,

$$IOL = s, \quad IOV = \frac{1}{2}\Delta, \quad OL = R', \quad SM = y, \quad LM = x$$

$$SV = SM + NV + MN$$

$$MN = GL = OL \frac{\sin LOG}{\sin OGI} = R' \frac{\sin (\frac{1}{2}\Delta - s)}{\cos \frac{1}{2}\Delta}$$

Hence,

$$T_s = y + x \tan \frac{1}{2}\Delta + R' \frac{\sin (\frac{1}{2}\Delta - s)}{\cos \frac{1}{2}\Delta} \quad (230)$$

Example. Total angle 42° , degree of curve $7^\circ 20'$, spiral, 10 chords of 24 ft each. What is the tangent distance?

Ans. $T_s = 416.24$.

Approximate formula for T_s . When selecting a curve with spirals to suit certain tangents use the following approximation:

$$T_s = R' \tan \frac{1}{2}\Delta + \frac{1}{2}nc \quad (231)$$

or, to the tangent distance for a simple curve add one-half the length of an appropriate spiral; the sum will be the approximate distance required. When a satisfactory selection has been made, compute the exact T_s by equation 230.

231. Given: a circular curve with equal spirals, joining two tangents; to find the external distance, $VH = E_s$ (Fig. 128).

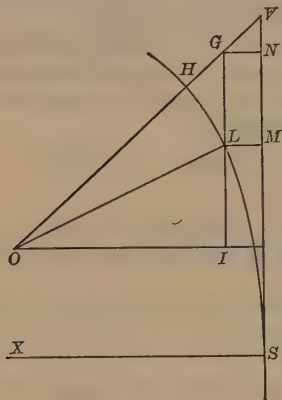


FIG. 128.

In the figure,

$$VH = VG + GO - OH$$

$$E_s = \frac{x}{\cos \frac{1}{2} \Delta} + R' \frac{\cos s}{\cos \frac{1}{2} \Delta} - R'$$

$$E_s = \frac{x + R'(\cos s - \cos \frac{1}{2}\Delta)}{\cos \frac{1}{2}\Delta} \quad (232)$$

Example 1. Total angle 42° , degree of curve $7^\circ 20'$, spiral 10 chords of 24 ft each. What is the external distance? Equation 232.

Ans. $E_8 = 59.298$.

For a small change in R' but with the same spiral being used, what will be the change in T_s and in E_s ?

If in equation 230 we give R' two values in succession and subtract, we shall have

$$\text{Diff. } T_s = \text{diff. } R \frac{\sin(\frac{1}{2}\Delta - s)}{\cos \frac{1}{2}\Delta} \quad (233)$$

Similarly, the corresponding change in E_s will be

$$\text{Diff. } E_s = \text{diff. } R' \frac{\cos s - \cos \frac{1}{2}\Delta}{\cos \frac{1}{2}\Delta} \quad (234)$$

Example 2. Changing the degree of curve in the previous example to $7^\circ 30'$ will make what change in the value of E_s ? (diff. $R' = 17.351$.) Equation 234.

Ans. Diff. $E_s = 0.997$. Hence, new value of $E_s = 58.301$.

For a small change in c , the chord length (n and, therefore, s being constant), and with the same radius as before, we have, from equation 232,

$$\text{Diff. } E_s = \frac{\text{diff. } x}{\cos \frac{1}{2}\Delta} \quad (235)$$

The change in c must not be so great as to make the last degree of curve of the spiral incompatible with the main curve.

Example 3. Changing the chord length to 26 ft in the foregoing example will make what change in the value of E_s ? (diff. $x = 1.118$.)

Ans. Diff. $E_s = 1.197$. New value of $E_s = 60.495$.

232. With E_s unchanged and the angles Δ and s the same, it is required to find the change in R' required by a change in x in order to close on the same tangents.

Solving equation 232 for R' , we have

$$R' = \frac{E_s \cos \frac{1}{2}\Delta - x}{\cos s - \cos \frac{1}{2}\Delta}$$

in which, by giving to x any two values and subtracting one result from the other, we derive

$$\text{Diff. } R' = \frac{-\text{diff. } x}{\cos s - \cos \frac{1}{2}\Delta} \quad (236)$$

The minus sign shows that R' decreases as x increases and *vice versa*.

The new value of x is taken from the table for the same value of n as before and such that the new spiral and resulting curve shall be consistent with each other.

Example. Let $D' = 7^\circ 20'$, $\Delta = 42^\circ$, $s = 9^\circ 10'$, $n = 10$, $c = 24$.

and, since

$$(\cos s - \cos \frac{1}{2}\Delta) = (\text{vers } \frac{1}{2}\Delta - \text{vers } s)$$

$$h \cos \frac{1}{2}\Delta = (R - R') \text{vers } \frac{1}{2}\Delta - (x - R' \text{vers } s) \quad (237)$$

The last term is the expression for p , whence

$$(R - R') \text{vers } \frac{1}{2}\Delta = h \cos \frac{1}{2}\Delta + p \quad (238)$$

and

$$p = (R - R') \text{vers } \frac{1}{2}\Delta - h \cos \frac{1}{2}\Delta$$

From the figure,

$$d = SA = SM - CM - AC = SM - IL - NO'$$

or

$$d = y - R' \sin s - (R - R' + h) \sin \frac{1}{2}\Delta \quad (239)$$

$$d = q - (R - R' + h) \sin \frac{1}{2}\Delta$$

The new degree of curve D' will be somewhat larger than the old. In view of the probable value of D' select a suitable spiral, and with the tabular value of p and any desired small value of h solve equation 238 for $(R - R')$, whence the approximate value of R' is known. From the table of radii correct R' to the nearest minute, and with this value of R' find h by equation 237 and d by equation 239. The value of q should be found by equation 229. The last term of equation 237 gives the correct value of p . Length, original, $d + \frac{1}{2}L$; new with spiral, $nc + \frac{1}{2}L'$.

If desirable, a comparison of lengths may be made with the approximate value of $(R - R')$ before finally fixing on R' .

Example. Given: D , $6^\circ 00'$; Δ , $50^\circ 12'$; select spiral n 9, c 26, s $7^\circ 30'$, from Table XXXVI.

Assume $h = 1$ ft and p from Table XXXVIII 3.12. (This value of p is approximate only.) Solve equation 238 for $(R - R') = 42.65$ which gives $R' = 912.72$. If the D' corresponding to this were taken, it would be in seconds; consequently, take R' for $D' = 6^\circ 16'$. Then compute $h = 0.991$ from equation 237, and find $p = 2.938$, $q = 114.179$, $d = 96.529$. Half-lengths, original, 514.86; new, 514.85.

234. *Given: a simple curve; to replace it by another with spirals that shall pass through the same middle point, H .*

In Fig. 129, H' and H will coincide. The two values of ON

will be $R - R' \cos s - x$, and $(R - R') \cos \frac{1}{2} \Delta$. Equating as before and collecting terms gives

$$R' = \frac{R \text{ vers } \frac{1}{2} \Delta - x}{\cos s - \cos \frac{1}{2} \Delta} \quad (240)$$

This will probably give a fractional value of D' , and, if it is necessary that h be exactly zero, this must be so taken. But, if a whole minute curve is taken, this will result in a very small value of h , either *plus* or *minus*, which must be noted.

Example. Given: D , 5° , Δ 48° , Spiral, n 7, c 26, p 1.59. Then, equation 238, approx. $(R - R') = 18.39$ and $R' 1127.89$. Assume $R' = 1127.50$ for $5^\circ 05'$. Then $p = 1.554$, $h = 0.077$, $q = 90.139$, $d = 82.469$.

235. *Given: a simple curve joining tangents; to compound it near each end so as to introduce a spiral (Fig. 130).*

Two methods of solution may be given: (a) by change in formulas previously deduced and (b) directly from a figure as in the two previous sections.

(a) In place of $\frac{1}{2} \Delta$ use some smaller angle θ , compounding at some point Q , and, by substitution, the last equation becomes

$$R' = \frac{R \text{ vers } \theta - x}{\cos s - \cos \theta} \quad (241)$$

Use the corresponding value of D' for the arc LQ . In equation 239 substitute θ for $\frac{1}{2} \Delta$, and solve for d .

Otherwise, assume the nearest tabular value for R' , and with this compute a new value for θ , thus fixing the position of the point Q . For this purpose, in equation 241 write (vers $\theta - \text{vers } s$) for $(\cos s - \cos \theta)$ and solve for vers θ , whence,

$$\text{vers } \theta = \frac{x - R' \text{ vers } s}{R - R'} \quad (242)$$

The numerator is evidently the new value of p .

In equation 239 make h equal zero, and write θ for $\frac{1}{2} \Delta$, whence

$$d = y - R' \sin s - (R - R') \sin \theta \quad (243)$$

(b) In Fig. 130 draw the line $O'N$ perpendicular to OA . Then,

$$ON = OO' \cos \theta = (R - R') \cos \theta$$

Also,

$$ON = OA - R' \cos s - x = R - R' \cos s - x$$

Equating and collecting terms yields equation 241.

Likewise, directly from the figure,

$$d = y - R' \sin s - (R - R') \sin \theta$$

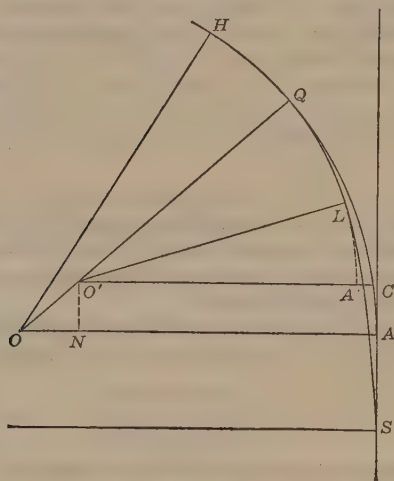


FIG. 130.

Example. Given: D 3° and spiral n 7, c 40, and $\theta = AOQ = 9^\circ 10'$.

By equation 241,

$$R' = 1729.31 \quad \text{or} \quad D' = 3^\circ 18' 45''$$

but, if $D' = 3^\circ 20'$ is assumed, by equation 242,

$$\text{vers } \theta = \frac{2.442}{190.96} = \text{vers } 9^\circ 10' 22'' \quad \text{and} \quad AQ = 305.76$$

By equation 243,

$$d = 279.802 - 139.865 - 30.442 = 109.495$$

Hence,

$$\text{Old line} = SAQ = 415.255; \quad \text{new line} = SLQ = 415.190$$

Note. We may assume R' without using equation 238, and, if θ be not satisfactory, try again. If we assume R' from D_s for $(n+1)$ of the spiral, we may use the tabular value of p for the numerator in equation 242.

236. *Given: a simple curve joining two tangents; to move the curve inward so as to provide clearance for spirals (Fig. 131).*

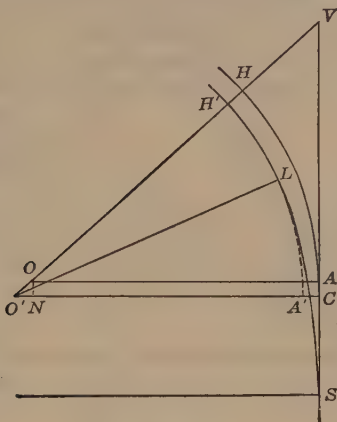


FIG. 131.

(a) *When the spirals are alike, the clearance is expressed by p in equation 228..*

Draw the line ON . Then,

$$O'N = O'O \cos \frac{1}{2}\Delta = h \cos \frac{1}{2}\Delta$$

Also,

$$O'N = R \cos s + x - R = x - R \text{ vers } s = p$$

$\therefore$

$$h = \frac{x - R \text{ vers } s}{\cos \frac{1}{2}\Delta} = \frac{p}{\cos \frac{1}{2}\Delta} \quad (244)$$

Similarly, the distance $SA = SC + CA$, or

$$d = q + h \sin \frac{1}{2}\Delta = q + p \tan \frac{1}{2}\Delta \quad (245)$$

The maximum displacement h occurs at the middle of the curve.

Equation 246 should be compared with equation 47 in the chapter on simple curves.

Example. Given: $D = 5^\circ$; $\Delta = 37^\circ$; and spirals $nc = 8 \times 30$; $n'c' = 10 \times 36$.

Then, $s = 6^\circ$; $s' = 9^\circ 10'$; $p = 2.615$; $p' = 5.483$; $q = 119.903$; $q' = 176.427$; $AC = 5.641$; $BC' = 2.931$; $d = 125.544$; $d' = 173.496$; $VV'H = 65^\circ 08'$; $VV' = 6.218$.

The necessity for differing spirals seldom occurs with a simple curve. If the displacement should be objectionable for any reason, one of the preceding methods may be adopted instead.

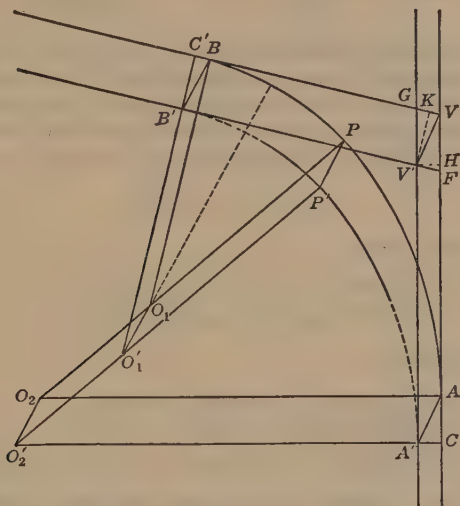


FIG. 133.

SPIRALS WITH COMPOUND CURVES

237. *Given: a compound curve joining tangents; to move the entire curve inward so as to provide clearance for spirals (Fig. 133).*

As suitable spirals will necessarily differ, the general method of the last section will apply here. Designate the spiral values by the same subscripts as the arcs themselves, let R_1 be less than R_2 , and $\Delta = \Delta_1 + \Delta_2$. With R_1 and s_1 find p_1 and

q_1 ; also with R_2 and s_2 find p_2 and q_2 , using equations 228 and 229.

Then, as in equation 246:

$$AC = \frac{p_1}{\sin \Delta} - \frac{p_2}{\tan \Delta} \quad BC' = \frac{p_2}{\sin \Delta} - \frac{p_1}{\tan \Delta} \quad (249)$$

If BC' should prove negative, give it the minus sign in the next formula.

$$d_1 = q_1 + BC' \quad d_2 = q_2 + AC$$

$$\tan VV'H = \frac{AC}{p_2} \quad VV' = \frac{p_2}{\cos VV'H}$$

The maximum displacement of the curve equals VV' and occurs on the radial line drawn parallel to VV' . If this radial line does not cut the curve between tangent points, the curve displacement varies between the limits p_1 and p_2 . The central angles of the resulting curve will be, respectively,

$$(\Delta_1 - s_1) \text{ and } (\Delta_2 - s_2)$$

Example. Given:

$$D_1 \ 8^\circ 20', \ \Delta_1 \ 25^\circ 03', \ n_1 c_1 \ 11 \times 24, \ s_1 \ 11^\circ$$

$$D_2 \ 3^\circ 20', \ \Delta_2 \ 38^\circ 57', \ n_2 c_2 \ 8 \times 45, \ s_2 \ 6^\circ$$

Then, we derive

$$p_1 \ 4.974, \ p_2 \ 3.923, \ q_1 \ 131.680, \ q_2 \ 179.883$$

$$AC \ 3.621, \ BC' \ 1.938, \ d_1 \ 135.301, \ d_2 \ 181.121$$

$$VV'H \ 42^\circ 42', \ VV' \ 5.338 \text{ max. at } 17^\circ 39' \text{ beyond } P$$

238. *Given: a compound curve joining tangents; to replace it by another with spirals on the same ground and of the same length, as nearly as may be (Fig. 134).*

The point of compound P will be preserved but moved outward by a small offset h , and each arc may then be treated separately as though it were half of a simple curve. As each arc will be somewhat sharpened, select suitable spirals accordingly, assume a small value for h (see Table XL for values of h in various cases), and compute the new radius R_1' and also R_2' , giving probably fractional degrees of curve. These may be adopted at once, or, if preferred, one new radius may

be assumed for the nearest minute. Then with this new radius a new value for h is computed and with this the value of the other new radius is recomputed.

With these final values proceed to compute d_1 and d_2 , and compare the lengths of the new and old lines. Draw the line $O_2'N$ perpendicular to O_2A .

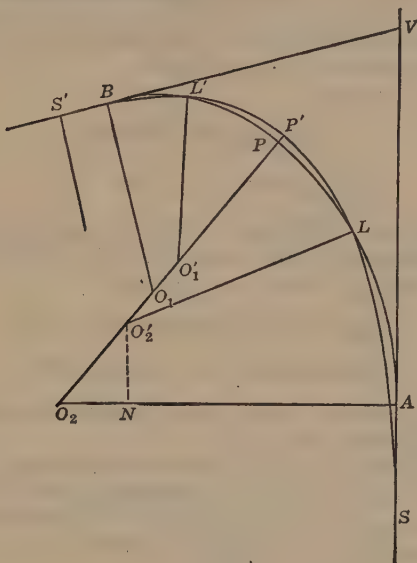


FIG. 134.

Now,

$$O_2A = R_2, \quad O_2'L = R_2', \quad \text{angle } AO_2P' = \Delta_2$$

Then,

$$O_2N = (R_2 + h - R_2') \cos \Delta_2$$

and also

$$= R_2 - R_2' \cos s - x$$

Collecting and rearranging terms, we have

$$R_2' = \frac{R_2 \text{ vers } \Delta_2 - (x + h \cos \Delta_2)}{\cos s - \cos \Delta_2} \quad (250)$$

and, since

$$\cos s - \cos \Delta_2 = \text{vers } \Delta_2 - \text{vers } s$$

$$h \cos \Delta_2 = (R_2 - R_2') \text{vers } \Delta_2 - (x - R_2' \text{vers } s) \quad (251)$$

Finally,

$$d = SA = y - R_2' \sin s - (R_2 + h - R_2') \sin \Delta_2 \quad (252)$$

The same formulas apply to the other arc; only the subscripts are changed where they occur.

Example. Given:

$$D_1 8^\circ; \Delta_1 29^\circ; n 9, c 20$$

and

$$D_2 6^\circ; \Delta_2 25^\circ 06'; n 9, c 26$$

Assume $h = 1$. Then, $D_2' = 6^\circ 16' 06''$; but, for $D_2' 6^\circ 16'$, $h = 0.99054$, and, for this value of h , $D_1' = 8^\circ 17' 56''$ (say) $8^\circ 18'$. Then, $d_1 = 76.474$; $d_2 = 96.981$.

$$\text{Length old line } 439 + 515.3 = 954.3$$

$$\text{Length new line } 439 + 514.9 = 953.9$$

Given: a compound curve; to apply spirals without disturbing the middle portion of the curve.

The methods discussed in §§ 234 and 235 apply here with merely a change in notation; P replacing H , and Δ_1 or Δ_2 or θ replacing $\frac{1}{2}\Delta$, as the case may require. In the case of three or more arcs in the curve only the terminal arcs are affected by the use of these methods.

239. *Given: a compound curve; to introduce a spiral between arcs at the point of compound P (Fig. 135).*

The arcs must be separated by a radial offset at P to afford clearance for the spiral, the sharper arc being inside the other. If it is new work, the sharper arc must be shifted along the tangent toward the vertex so that it may be inside the other arc. If the curve actually exists, the sharper arc must be compounded at some point so as to bring it inside the other. In general, the spiral and offset bisect each other. In Table XXXVI under any one chord length find two values of D_s corresponding, as nearly as possible, to D_1 and D_2 , and use the portion of the spiral included between them; lay off one-half this length on each arc from P , for the new compounding

points F and H . From the point F the spiral FH may be located by deflections from the local tangent, by using only the portion of spiral selected and the deflections given *below* the zeros in Table XXXV for the point number represented by F .

Or the spiral may be located from H towards F by using the deflections given *above* the zeros in Table XXXV for the

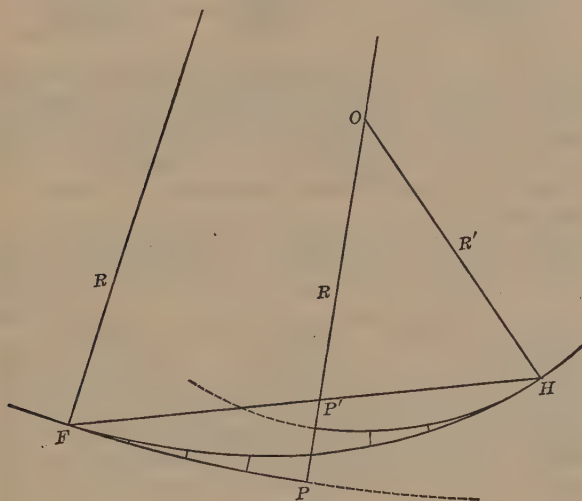


FIG. 135.

instrument at the point number represented by H . The sum of the angles taken from the two arcs equals the spiral angle for the portion of the spiral used. Should the distance FH prove to be a little longer or shorter than the spiral, the several chord lengths may be slightly altered.

Now the linear offsets from arc to spiral at the chord points are the same as from a tangent, if F or H is regarded as the point of spiral S , and the points are numbered from them as usual; the offset is equal to x given in the table. Thus, if the spiral is eight chords long, the fourth point from either end will be at P ; consequently, the offset PP' will equal $2x$ for $n = 4$ in the proper table.

But, when the spiral has an odd number of chords, the half-length will bisect the middle chord, and the value of x is found by multiplying the chord by the coefficient here given opposite the half-length of spiral.

COEFFICIENTS FOR x AT HALF-CHORDS

n		n		n	
1.5	0.00364	4.5	0.05999	7.5	0.24711
2.5	0.01273	5.5	0.10397	8.5	0.35200
3.5	0.03054	6.5	0.16538	9.5	0.48288

The spiral may be located by offsets. First chord lengths are laid out from P on one arc, and from P' on the other, and then x is set off at each point till F or H is reached, where $x = 0$. If the spiral long chord FH be required, it may be computed by equation 226 for the portion of the spiral actually used.

Example. Given: a compound curve of $D\ 4^\circ$ and $D'\ 12^\circ$; to introduce a spiral at the P.C.C. In Table XXXVI under $c\ 21$ find at $n\ 5$, $D_s\ 3^\circ\ 58'$ and at $n\ 15$, $D_s\ 11^\circ\ 55'$; therefore, the spiral will extend from point 5 to point 14, and the spiral angle s will be $(17^\circ\ 30' - 2^\circ\ 30') = 15^\circ$. Divide this between the arcs in the ratio of their degree of curve, or $\frac{1}{4}$ and $\frac{3}{4}$ parts, $3^\circ\ 45'$ on the 4° curve, and $11^\circ\ 15'$ on the other. This takes 93.75 ft on each arc, total 187.50 ft; but the spiral measures $9 \times 21 = 189$ ft; the difference, 1.50 ft divided by 9 gives a correction 0.17 for each chord length; hence, $c = 20.83$. The point $n\ 5$ is taken at F , and, from Table XXXV "Inst. at 5" the deflection for point 6 is $30'$. Make this and the succeeding deflections up to $n\ 14$ or H . At H deflect from chord HF to find tangent $8^\circ\ 36'\ 45''$ (found "Inst. at 14" $n\ 5$) to complete the 15° .

The middle point of the spiral is $n\ 4.5$ for which the coefficient is 0.06; hence, the clearance $p = 2 \times 21 \times 0.06 = 2.52$ for separation of curves at P .

Field and Office Work

240. A spiral may be set out on the ground in either direction by using the proper list of deflections, according to the point n at which the transit is placed, but to secure perfect agreement with the tangent it is better to proceed from the

tangent point with each spiral and afterward connect them by the intervening curve. The several points of the spiral, however, are not required except for track laying, and in the earlier stages of the work it is sufficient to locate the extremities of the spiral by its long chord SL . Any regular station of the survey which falls on the spiral may be located by treating it as a *plus* between chord points, making the deflection to it accordingly by ordinary interpolation. Strictly speaking, there is a second difference to be applied to the deflection so found (minus when running from S and plus when running from L), but as this amounts only to $12''.5$ at the middle of a chord, it may usually be ignored. A transit point, if required on a spiral, will be located at a regular chord point.

In a difficult country, where the line requires close adjustment to the contour, it is wise to ignore all spirals until a satisfactory location has been obtained. Spirals may then be introduced by any of the methods described. Only in a flat country, or where a very careful paper location has been projected, is it worth while to set out spirals at the first running.

In projecting a paper location it is desirable to have at hand a set of circular templets cut to the scale of the map and representing convenient degrees of curve. After finding by trial a curve that fits the topography when touching the tangents, locate the tangent point A by a perpendicular from the center, and withdraw the templet a little to give the necessary clearance p for the spiral. The distance moved along the line VO is

$$h = \frac{p}{\cos \frac{1}{2}\Delta} \quad (253)$$

The clearance may be too small to be shown accurately to scale, but the distance AS may be computed (equation 245) and laid off to locate S from which the point L may be located by its coordinates, x and y . Or the entire tangent distance VS may be computed and scaled. The spiral may be drawn with a suitable curved rule. It should sensibly bisect the offset p and be bisected by it very nearly.

When curves predominate, these should be drawn first to suit the contours, but far enough apart to admit the necessary spirals and a bit of tangent. The tangent lines are then

drawn to touch short arcs outside the curves at the distance p . Then, from a radius drawn perpendicular to the tangent lay off q to locate S and $R \sin s$ to locate M opposite L .

Table XXXIX supplies the quantities required for projecting curves and spirals in either field or office work for a selected list of simple curves. It furnishes also a means of computing correctly the spiral tangent T_s for any curve in the list by the use of the formula,

$$T_s = T + q + p \tan \frac{1}{2}\Delta \quad (254)$$

in which T is the tangent distance for the simple curve. (The student should derive this equation.) Much time may be saved by adopting in practice the curves listed in this table.

THE TEN-CHORD SPIRAL

241. The ten-chord spiral. Instead of the multicomponent curve, discussed in this chapter as the railroad spiral, we may use a curve of variable radius to effect the same result, namely, the easy transition on a railroad track from a tangent to a circular curve.

The essential condition in this case is that the variable radius of curvature at any point of the spiral shall be inversely as the length of arc to that point from the main tangent point. This secures a uniformly increasing degree of curvature from the tangent to the given circular curve and accords with the regular rise of the outer rail to the elevation required.

A spiral of this form has been adopted by the American Railway Engineering Association and is called "The Ten-Chord Spiral" from the fact that, in every instance, it is designed on ten equal chords, which, taken together, constitute the length of the spiral. Although theoretically the length of spiral signifies the length of its arc, yet in the case of flat arcs, or where the degree of curve does not exceed 8° or the spiral angle does not exceed 15° , the measurement of the spiral by its chords gives practically correct results. Beyond these limits, however, certain small corrections become necessary.

242. In the discussion of this spiral we have adopted the following (Fig. 136):

Notation

r = radius of curvature at any point of the spiral
 R = radius of the circular curve, and limiting value of r
 d = degree of curvature at any one point of the spiral
 D = degree of curve of the circular curve, and limit of d
 l = length of spiral arc from S to any point on the spiral
 L = total length of spiral arc, and limiting value of l
 s = central angle of the spiral up to any point
 S = total spiral angle up to L , and limiting value of s
 i = deflection at S from the tangent to any spiral point
 I = total deflection to the point L , and limiting value of i

243. From the condition previously stated we have, at once,

$$\frac{r}{R} = \frac{L}{l} \quad (255)$$

and, for flat arcs generally,

$$\frac{d}{D} = \frac{l}{L} \quad (256)$$

Since d is zero at the tangent point and increases uniformly to its limit D at L , its average value is $\frac{1}{2}D$, and this multiplied by the length of the spiral in stations of 100 ft, or $L/100$, gives the central angle of the whole spiral S (compare equation 7).

$$S = \frac{LD}{200} \quad (257)$$

Similarly, for any other point of the spiral,

$$s = \frac{ld}{200} \quad (257A)$$

Dividing s by S and substituting from equation 256, we have

$$\frac{s}{S} = \frac{l^2}{L^2} \quad (258)$$

or the spiral angles are to each other as the squares of the lengths of spiral measured from the tangent point S .

For the deflection angle i , $\sin i = x/l$ approx., and, when i is small,

$$i = \frac{x}{l} = \frac{D \cdot l^2}{600L}$$

which, compared with equation 259, gives

$$i = \frac{s}{3} \quad (261)$$

when s does not exceed 15° .

Let x, y be the variable coordinates of the spiral, the main tangent being taken as the axis of Y with the origin at S . When s does not exceed 15° , x is given by equation 260 and y by

$$y = l \cdot \cos i \quad (262)$$

244. All the foregoing formulas give values for any point of the spiral, but the only points to be considered are at the intersections of the ten equal chords which measure its length. Let c be the length of one of these chords, and let a_1, a_2, a_3 , etc., be the angles which these chords produced make with the tangent. To find their values:

If through any chord point B of the spiral (Fig. 137) and with the radius of curvature for that point we draw a circular arc having a common tangent at B , and from that point draw the short chord c to the spiral at K , and another of the same length to the circular arc at G , then, by the law of the spiral the angle GBK between these chords is equal to i_1 the deflection angle at S for the first chord c .

Take any point as B (Fig. 137) on the spiral. Then, if BK is one chord distance, the angle KBG is the same as the angle at the point S between the main tangent SE and one chord. Similarly, the angle at B between the circle GB and a forward point on the spiral two chord distances from B is the same as the angle at S between the main tangent SE and the second point on the spiral, and so on. This is called the "law of the spiral."

Let the chord BK be the n th chord of the spiral, K the n th point, and B the point $(n-1)$. Since from equation 258 the spiral angles are to each other as the squares of the dis-

Then $a_n = \text{angle } KBJ = \text{the sum of the spiral angle for the point } B (= HBJ) \text{ plus the deflection angle } HBG \text{ plus the angle } GBK, \text{ or, for the } n\text{th chord,}$

$$a_n = [(n-1)^2 + (n-1) + \frac{1}{3}]s_1 \quad (263)$$

or, in terms of a_1 which equals i_1 ,

$$a_n = (3n^2 - 3n + 1)a_1 \quad (263A)$$

If in the parenthesis we substitute in succession the numbers from 1 to 10 for n we get a series of coefficients of a_1 for all the chords of the spiral, namely, 1, 7, 19, 37, 61, 91, 127, 169, 217, 271.

(Observe that these numbers are the first differences of the cubes of the serial numbers, 1 to 10; their differences are multiples of 6, and their second difference is 6, a constant.)

The values of a thus obtained serve only the purpose of deriving precise values of the coordinates, x and y , for the ten chord points when s is too large to admit of the assumption, $s = \sin s$, or $\sin i = x/l$, as is done in § 243.

245. Having the angle a which any chord c makes with the main tangent, multiply c by $\cos a$ and $\sin a$, respectively, to obtain the projection of that chord on the tangent and perpendicular. The successive addition of these projections gives the values of the coordinates, x and y , for the chord points of the spiral. This work has been done and tabulated once for all for various values of S and L . We may then obtain the precise value of the angle i for any point of a given spiral by

$$\tan i = \frac{x}{y} \quad \text{or} \quad \tan I = \frac{X}{Y} \quad (264)$$

246. Let C be the long chord SL of the spiral, and let U and V be the tangents SE and EL of the spiral, as in Fig. 136; then, as in § 228, we have at once,

$$C = \frac{Y}{\cos I} \quad \text{or} \quad C = \frac{X}{\sin I} \quad (265)$$

$$U = Y - X \cot S; \quad V = \frac{X}{\sin S} \quad (266)$$

in which X , Y , and S are taken from the table for the given spiral. Since the angle at E equals S , the deflection angle ELS is

$$I' = S - I \quad (267)$$

247. If the circular curve of radius R were extended backward through the angle S , from L to A' , the length of the extension would be half that of the spiral, or $\frac{1}{2}L$, and the point A' would be the tangent point of a tangent parallel to the main tangent.

Let q , p , be the coordinates of the point A' as in the figure. Then, as in § 229,

$$q = Y - R \sin S \quad \text{and} \quad p = X - R \text{ vers } S \quad (268)$$

in which X and Y are the coordinates of the point L .

Values of q and p are given in Table XLVIII for certain values of D and L ; also in Table XLIX are given the coefficients of D and L for finding q and p .

248. Let T_s , E_s be the tangent distance and external distance to the vertex for the combined spiral and circular curve, and let Δ be the total angle between tangents. Then, from Fig. 136, we have

$$T_s = (R + p) \tan \frac{1}{2}\Delta + q \quad (269)$$

$$E_s = (R + p) \text{ ex sec } \frac{1}{2}\Delta + p \quad (270)$$

249. On location surveys it is desirable to do all the field work in a forward direction since the line and field notes are continuous, and the second or closing spiral of a curve should form no exception to this rule. For forward work from L' equation 267 gives the deflection I' and equation 265 gives the long chord C , by which the closing tangent point S' may be reached. After the position of this point has been verified and the closing angle I tested, any station stakes required on the spiral may be set. A station will usually occur as a "plus" between the spiral chord points.

It would be convenient to have a table of deflections for the spiral from the common tangent at the point L or L' , but these deflections may be computed with little trouble since the deflections from points on the circular curve LA' pro-

duced to spiral points are the same, point for point, as the deflections from the tangent given in Table XLV for the other end of the spiral. With a given value of the chord c take a series of points from L on the circular curve LA' , and compute the deflections to them from the common tangent, deduct from these the tabular values of i_1, i_2, i_3 , etc., found in Table XLV, and the differences will be the deflections required from the common tangent at L to the several spiral points, 9, 8, 7, etc. These results are correct up to 15° practically.

When centers are to be given for track laying it is desirable that the transit be set at the main tangent point in every case, as this insures greater precision in alignment on the flat part of the spiral and a perfect connection with the tangent.

Example. Given: a spiral of 300 ft to connect a 6° curve with the following tangent, to find the deflections from the common tangent at L' .

By equation 257; $S = 9^\circ, s_1 = 0.09^\circ = 5.4', i_1 = 1.8', c = 30$.

Point	Circle		Table XLV		Deflec.
L'	$0^\circ 00.0'$		$0^\circ 00.0'$		$0^\circ 00.0'$
9	0 54	—	0 1.8	=	52.2
8	1 48	—	7.2	=	1 40.8
7	2 42	—	16.2	=	2 25.8
6	3 36	—	28.8	=	3 07.2
5	4 30	—	45.0	=	3 45.0
4	5 24	—	1 04.8	=	4 19.2
3	6 18	—	1 28.2	=	4 49.8
2	7 12	—	1 55.2	=	5 16.8
1	8 06	—	2 25.8	=	5 40.2
S'	9 00	—	3 00.0	=	6 00.0

The same result will be obtained by multiplying i_1 by the coefficients in the last column of Table XLVI. For a check the second difference of the deflections is a constant and equal to $2i_1$.

250. Should it become necessary to use a transit point on the spiral, one of the chord points will be selected for this purpose, preferably point 5. Compute the deflections from the tangent at such a point on the principle given in the last section, using for the circle, however, the circle described by the radius of curvature of the spiral at the point selected. To these deflections apply the tabular values of i as before, deducting them for points between the transit and the main tangent, but adding them for points between the transit and the circular curve.

Example. Given: a spiral of 300 ft located from either end as far as point 6; to find the remaining deflections from the local tangent at that point, in connection with a 6° curve.

At point 6 the degree of curvature is $6D/10$ or 3.6° , $c = 30$ ft, and $i_1 = 1.8'$, as before.

Point	Circle		Table XLV		Deflec.
S	$3^\circ 14.4'$	—	$1^\circ 4.8'$	=	$2^\circ 9.6'$
1	2 42.0	—	45.0	=	1 57.0
2	2 09.6	—	28.8	=	1 40.8
3	1 37.2	—	16.2	=	1 21.0
4	1 04.8	—	7.2	=	57.6
5	32.4	—	1.8	=	30.6
6	00.0		0.0		00.0
7	32.4	+	1.8	=	34.2
8	1 04.8	+	7.2	=	1 12.0
9	1 37.2	+	16.2	=	1 53.4
L	2 09.6	+	28.8	=	2 38.4

Note that the spiral points are numbered from the tangent toward the curve, regardless of the direction in which the line is measured. When point 6 has been established, the entire spiral may be located from this point, using these deflections. The same deflections may be obtained by multiplying i_1 by the coefficients in column 6 of Table XLVI. The second difference is constant.

251. When it is desired to locate a spiral with the tape without a transit, first find X , the offset to the end of the spiral, and (since offsets vary as the cubes of their distances from the tangent point) divide the spiral into any convenient number of equal parts, divide X by the cube of this number for the first offset, and multiply this offset by the cube of succeeding numbers for the other offsets. Stretch a wire or cord to mark the line of the tangent, lay off from S along the spiral the length of chord adopted, setting each forward pin at the computed offset distance from the wire. The offset must be at right angles to the wire. This method is inferior to the transit method and should be used only in case of emergency. By dividing the spiral into eight equal parts the computation of offsets is somewhat simplified, the middle offset being $\frac{1}{8}X$, the first quarter offset one eighth of this, and the first offset one eighth of the latter; since 8 is the cube of 2.

Example. Given: $D = 8^\circ$ and $L = 280$ ft; to locate the spiral of ten points from the tangent. By Table XLVIII, for point 10, find $X = 18.20$; for point 1, point off three places,

giving 0.0182; multiply this by 8, giving 0.1456 for point 2; and again by 8 for point 4, giving 1.1648; and again by 8 for point 8, giving 9.3184. Now multiply 0.0182 by 27 for point 3, giving 0.4914, and this by 27 for point 9, giving 13.2678, and also by 8, giving 3.9312 for point 6. Finally, for point 7 multiply 0.0182 by 343, giving 6.2426. For a check set these products in order in a column, and take their differences; the third difference is constant, 0.1092. It is proper to compute with four decimal places, although only two places can be used on the ground.

252. Although the length of spiral and degree of curve are arbitrary, they bear a certain practical relation to each other, and, although the curve as a whole must suit the topography, the spiral must not be too short to provide an easy transition, nor yet so long as to crowd the circular curve and increase unduly its degree. For limits in length of spiral consult Table XXXIII, having regard also to the probable speed of trains. Owing to its varying curvature a long spiral is less easily kept in true alignment than a circular curve. As a rule the two spirals of the same curve should be alike.

253. To introduce a spiral between arcs of a compound curve. After *relocating one of the arcs to provide the necessary offset at the point of juncture P* , assume the length of spiral L , and lay off half of this from P on each arc. Let D be the difference in degree of curve of the two arcs, and by equation 257 find S , and from Table XLV take out the deflections required. The transit being set on the flatter arc at five chords from P , find the chord points on the arc, and make the spiral deflections from these to locate the corresponding points of the spiral; or *add* these deflections to the tangential deflections for the arc points, and deflect the *sums* from the local tangent to the spiral.

If the transit is set on the sharper arc at five chords from P , proceed in the same manner, but *subtract* the deflections and deflect the *differences* from the local tangent. This method is evidently the same as that described in § 250. The required interval between arcs at the point P is twice the offset at the fifth point and may be calculated. The entire spiral may be located by offsets from the arcs, the offsets being in the ratio of the cubes of the point numbers and equal to the offsets from tangent to spiral described in § 251.

254. To distinguish between the several transit points at which changes in alignment occur the American Railway Engineering Association has adopted the following notation: A transit point is designated by the initials of the two lines which unite at that point, the initials being given in the order in which the station numbers of the survey increase. Thus we have:

T.C. for change from Tangent to Circle.

T.S. for change from Tangent to Spiral.

S.C. for change from Spiral to Circle.

C.C. for change from Circle to Circle of differing degree.

C.S. for change from Circle to Spiral.

S.T. for change from Spiral to Tangent.

C.T. for change from Circle to Tangent.

CHAPTER X

CROSS SECTIONS

STANDARD METHODS

255. Field measurements for earthwork. As soon as the preliminary-location center line has been staked out, measurements are made in the field from which the required quantities of excavation and embankment can be accurately computed. Similar measurements are made on the completion of the final location and often for the monthly estimates of work completed during the period of construction. Owing to the irregularities of the ground, it is impossible to determine these quantities with mathematical precision, but a standard procedure has been developed that is simple to use both in the field and in the office and gives results that are sufficiently accurate for practical purposes.

The procedure consists of determining the areas of cross sections of the required earthwork at frequent intervals along the line and computing the volumes of each cut or fill from these areas and the distances between them. The cross sections are taken on vertical planes at right angles to the line. Where the ground surface is reasonably smooth they are taken at every station or half station. Where the ground is irregular and at the ends of cuts they must be taken at more frequent intervals, as described in Chapter XI. As the volumes of cuts and not the fills are the basis of payment, more care is used in cut measurement. Rock excavation, which is not only more irregular but also much more expensive, must be measured with the greatest care of all and, accordingly, requires the greatest number of cross sections.

Sometimes the areas can be computed directly from the field notes. But to prevent error, and usually to assist in computing the areas, the cross sections are usually plotted to scale on

cross-section paper. Cross-section paper is ruled in inch and tenth-of-an-inch squares.

256. Shape of cross sections. The shape of a cross section depends on four elements (Fig. 138):

1. The elevation (or grade) G of the finished subgrade center line.
2. The desired shape of the finished subgrade surface, AGB .
3. The side slopes employed, AE and BD .
4. The profile of the ground surface at right angles to the line, $ELCFD$.

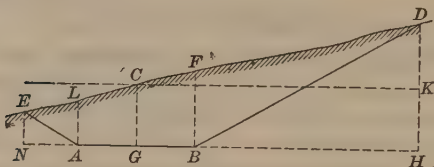


FIG. 138.

The grade. The grade is established by application of principles elsewhere described and given in detail in Chapter XVIII.

The shape of the finished subgrade. The shape of the finished subgrade frequently called the base or roadbed depends on the design and is shown in the plans on the "typical cross sections."

The usual cross section of a railroad subgrade is a straight level line. Sometimes ditches in cuts are included, but more frequently the roadbed is merely widened to allow for them.

Highway subgrades are more intricate. They are usually crowned, are often brought up to the level of the pavement on the shoulders and on the center strips, include ditches, and are sometimes raised on the outside for parkways and sidewalks.

The side slopes. The side slopes begin at the outside limits of the base. They are extended up or down at the given slope until they reach the ground profile. The slope is designated by the ratio of horizontal to vertical. A 2:1 slope extends 2 ft on the horizontal to 1 ft on the vertical. Except on light highway fills the slope used is the maximum at which the material encountered will stand. The usual slope ratio

for earth is $1\frac{1}{2}$ horizontal to 1 vertical for both excavation and embankment. Damp clay and solid gravel beds will stand for a time in cuts at 1 to 1, or an angle of 45° , but this cannot be depended on permanently. On the other hand, fine sand and very wet clay may require slopes of $1\frac{3}{4}$ to 1 or 2 to 1. Exceptional cases require slopes of 3 or 4 to 1. In rockwork the slopes are usually made at $\frac{1}{4}$ to 1 for solid, $\frac{1}{2}$ to 1 for loose, and 1 to 1 for very loose rock, liable to disintegrate. Rock embankments stand at 1 to 1. On light highway fills, where no guard rail is necessary, slopes of 3:1 or 4:1 are frequently used to reduce damage to vehicles that may run off the highway.

The profile of the ground surface. The profile of the ground surface at right angles to the center line is determined in the field. For railroad cross sections it is usual practice to determine if possible three elevations only, one at the center line, and one on each side far enough to include the entire section and any minor shifts in alignment that may later be required. A profile of this kind is called a **three-level section**. Where large breaks occur, a three-level section cannot be used, as auxiliary elevations and offsets must be measured.

Highway cross sections are usually much wider than railroad cross sections and seldom as deep, and the ground profiles often include an existing roadway. Minor irregularities not only are more frequent but they also form a large percentage of the total area and, accordingly, require many auxiliary measurements.

The process of measuring ground profiles is called **cross-sectioning**. Elevations are usually measured with a level, rod readings on the ground are taken to the nearest tenth of a foot, the perpendicularity of the section to the line is estimated, and offsets are measured with a metallic tape often called, for this reason, a **cross-section tape**.

257. Plotting cross sections. Cross sections are plotted on cross-section paper, usually at a scale of 1 in. = 10 ft. They may be plotted by elevations or by cuts and fills as explained below under **slope staking**. If they are plotted by elevations, the typical base is drawn with the center line at the grade elevation, and the ground profile is plotted from the field notes. The slopes are then extended from the extremities of the typical base at the required slope until they reach the ground profile.

SLOPE STAKING

258. When the final location line is established, slope stakes are set at every station or half station to guide the contractor in shaping the earthwork. A slope stake is placed in the ground at the point where the slope of the cut or fill will meet the ground surface. On each stake is marked its offset from the center line and the vertical height from the ground at the stake to the grade of either the adjacent edge of the base or the center line of the base. When the grade is below the stake position, the vertical height is marked **cut**; when above,

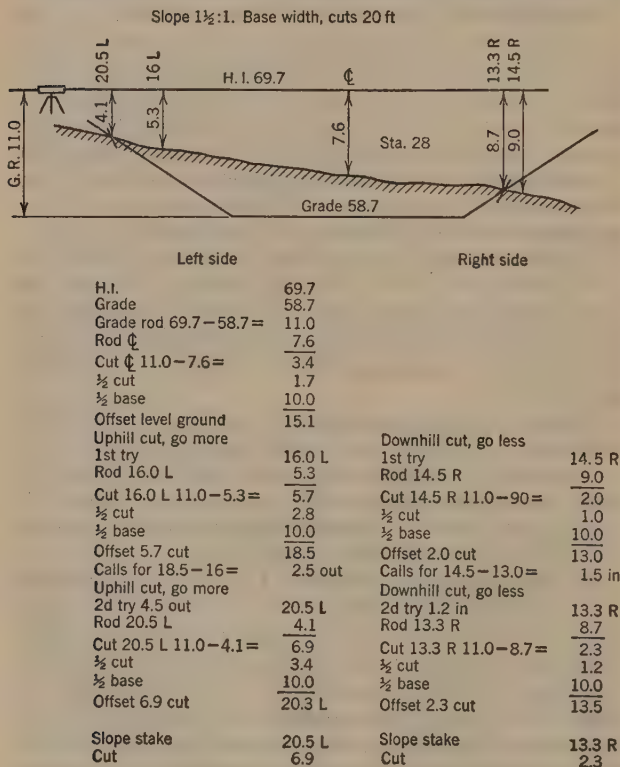


FIG. 139.

fill. Slope stakes are set by a method of trial and error as outlined in the next paragraph and illustrated in Figs. 139 and 140.

A list of grades for the stations where the slope stakes are to be set must be available in the field. Beginning at the nearest benchmark, a line of levels is carried to the vicinity of the work and an H.I. is established from which the necessary sights can be taken. The work is continued according to the following steps (Note Figs. 139 and 140):

1. **Compute the grade rod.** The grade rod is the rod reading that would be obtained from the *existing* H.I. if the foot of the rod were at grade.

$$\text{Grade rod} = \text{H.I.} - \text{grade} \quad (271)$$

A minus value for the grade rod indicates that the rod would be held upside down.

2. **Find the depth of cut or fill at the center line.** Take a rod reading at the center-line stake, and compute the center-line cut.

$$\text{Cut} = \text{grade rod} - \text{rod} \quad (272)$$

A minus value indicates *fill*.

The back of the center-line stake is marked with the value computed, cut being indicated by *C* and fill by *F*.

It may be noted that, even on a fill section where the grade is above the instrument, the algebraic signs will operate properly.

3. **Have the rod held at the estimated offset for the slope stake.** To make this estimate proceed as follows:

(a) Compute the offset for the slope stake as if the ground were level.

$$\text{Offset} = \frac{1}{2} \text{ base} + \text{slope} \times \text{cut or fill at edge of base}$$

Since the edge of the base is often level with the center of the base and the slope is often $1\frac{1}{2}:1$, this computation is usually made by adding $\frac{1}{2}$ the cut or fill to the center cut or fill without regard to sign and then adding $\frac{1}{2}$ the base.

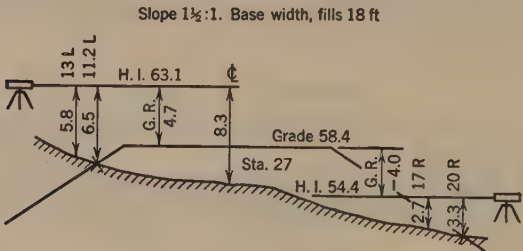
(b) Use the following rule. *On uphill cuts or downhill fills, go more—on uphill fills and downhill cuts go less.*

By *uphill* is meant that the ground rises as the offset increases. The slope of a cut then must be extended beyond the

point necessary for level ground. The other possibilities may be similarly interpreted. Accordingly, have the rod held at a somewhat greater or less offset than that for level ground according to the circumstances.

4. Have the rod read, and compute the cut or fill at this point, using the formula for cut previously given.

5. Compute the required offset for this depth of cut or fill, using the formula for offset given previously.



Left Side	
H. I.	63.1
Grade	58.4
Grade rod $63.1 - 58.4 =$	4.7
Rod ϕ	8.3
Cut ϕ $4.7 - 8.3 =$	-3.6
$\frac{1}{2}$ fill	1.8
$\frac{1}{2}$ base	9.0
Offset level ground	14.4
Uphill fill, go less	
1st try	13.0 L
Rod 13.0 L	5.8
Cut $13.0 L$ $4.7 - 5.8 =$	-1.1
$\frac{1}{2}$ fill	0.6
$\frac{1}{2}$ base	9.0
Offset 1.1 fill	10.7
Calls for $13.0 - 10.7 =$	2.3 in
Uphill fill, go less	
2d try 1.8 in	11.2 L
Rod 11.2 L	6.5
Cut $11.2 L$ $4.7 - 6.5 =$	-1.8
$\frac{1}{2}$ fill	0.9
$\frac{1}{2}$ base	9.0
Offset 1.8 fill	11.7
Slope stake	11.2 L
Fill	1.8

Right Side	
H. I.	54.4
Grade	58.4
Grade rod $54.4 - 58.4 =$	-4.0
Cut ϕ	-3.6
Offset level ground	14.4
Downhill fill, go more	
1st try	17.0 R
Rod 17.0 R	2.7
Cut $17.0 R - 4.0 - 2.7 =$	-6.7
$\frac{1}{2}$ fill	3.4
$\frac{1}{2}$ base	9.0
Offset 6.7 fill	19.1
Calls for $19.1 - 17.0 =$	2.1 out
Downhill fill, go more	
2d try 3.0 out	20.0 R
Rod 20.0 R	3.3
Cut $20.0 R - 4.0 - 3.3 =$	-7.3
$\frac{1}{2}$ fill	3.6
$\frac{1}{2}$ base	9.0
Offset 7.3 fill	19.9
Slope stake	20.0 R
Fill	7.3

FIG. 140.

6. Have the rod held at a second estimated offset for the slope stake. To make this estimate proceed as follows:

(a) If the required offset, computed in step 5, is greater than the actual offset, move the rod further out, and vice versa.

(b) The distance that the rod is moved should be equal to the difference between the two offsets modified by the rule for uphill cuts or downhill fills. "Go more" indicates, "move a greater distance, either in or out as indicated."

7. Repeat steps 4 and 5. If the required offset agrees with the actual offset within $\frac{1}{2}$ ft (or any desired limit), set the slope stake at the position of the rod. If the agreement is not close enough, repeat step 6, etc.

8. Mark the slope stake with the station number, the actual offset, and the cut or fill.

CROSS SECTIONS FROM SLOPE-STAKE NOTES

259. Frequently the slope-stake notes are used for computing the areas of the cross sections. When this is contemplated, auxiliary rod readings are taken at breaks in the ground profile. The cuts or fills at these points are computed from the grade rod and recorded in the same manner as the slope stakes.

The areas of the cross sections should be computed directly from the cuts and fills rather than from the differences in elevation.

If the cross sections are plotted, the base is drawn first according to the typical cross section, and the ground surface is plotted by measuring the cuts and fills from the base, not by plotting elevations.

260. **Complete field notes.** Many engineers prefer to record, in addition to the usual slope-stake notes, the complete leveling notes involved. These serve as a permanent record of the actual elevations of the ground at the slope stakes and also as a check on the slope-stake notes. Cuts or fills are checked by the following formula:

$$\text{Cut} = \text{elevation} - \text{grade} \quad (273)$$

Figure 141 shows this form of notes for the work of setting the slope stakes illustrated in Figs. 139 and 140.

Sta.	+	H.I.	-	Rod	Elev.	Gds.	Cut	L	£	R
B.M.*18	4.61	68.89			64.28					
T.P.*1	3.03	69.68	2.24		66.65					
Sta.27				7.6	62.1	58.7	3.4	(G.R. 11.0)		
20.5L				4.1	65.6	58.7	6.9	$\frac{20.5}{C6.9}$	$\frac{0}{C3.4}$	$\frac{13.3}{C2.3}$
13.3R				8.7	61.0	58.7	2.3			
T.P.*2	1.87	63.12	8.43		61.25			(G.R.4.7)		(G.R.-4.0)
Sta.28				8.3	54.8	58.4	-3.6	$\frac{11.2}{F1.8}$	$\frac{0}{F3.6}$	$\frac{20.0}{F7.3}$
11.2 L				6.5	56.6	58.4	-1.8			
T.P.*3	2.42	54.43	11.11		52.01					
20.0R				3.3	51.1	58.4	-7.3			
T.P.*4	12.76	65.87	1.32		53.11					
B.M.*18			1.60		64.27					

FIG. 141.

261. Sidehill section. A section is so named when its base or roadbed is partly in cut and partly in fill. Set the rod at the grade-rod reading, and move the rod along the section until the grade point is found; note its distance from the center and set a stake there, marked 0.0, facing it downhill. Find and note other points as in the other cases, but observe that $\frac{1}{2}$ base has different values in cut and fill and also that s may have two values, one for cut and one for fill. When the cut on the lower side is less than 1 ft, it is well to go beyond that stake and set a grade stake, noting the distance out, thus changing a thorough cut into a sidehill section.

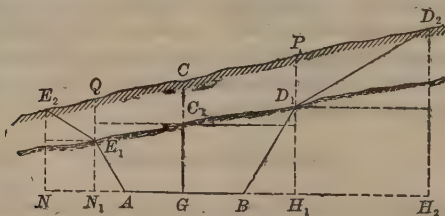


FIG. 142.

262. When two materials are found in the same section, as rock overlaid with earth, each material requires its own slope, and a **compound section** is the result. *To stake out work of this description*, the depth of the earth to the rock must be known and may be nearly ascertained by reference to an adjacent section already excavated (Fig. 142).

Let b be the width of the base AB
 d be the depth at the center line CG
 a_1 be the depth of earth at C
 a_2 be the depth of earth at P or Q
 s_1 be the ratio of rock slope
 s_2 be the ratio of earth slope

Then,

$$x = \frac{1}{2}b + s_1(d - a_1 \pm y_1) + s_2(a_2 \pm y_2) \quad (274)$$

in which x = distance out; y_1 = difference of rod readings on the *rock* at C_1 and D_1 , or C_1 and E_1 ; and y_2 = difference of rod readings on the *surface* at P and D_2 , or at Q and E_2 . The upper sign applies to the upper side; the lower sign to the lower.

This is one of the instances where a formula makes a comparatively simple matter appear difficult.

It is better, however, to make an indefinite cross profile at first, driving two reference stakes quite beyond the section limits, and, when the contractor has removed the earth from between D_1 and E_1 , indicate to him those exact points by marks on the rock, and also set the slope stakes at D_2 and E_2 .

263. Terminal sections. A grade stake is set on the center line where it passes from cut to fill and also on each of the base lines if the contour crosses the line obliquely, and a section is required at each to define the terminal pyramids. The grade stakes are located by trial on the ground, the grade-rod reading being used. Figure 143 illustrates this case, showing the roadbed in plan and the place of cross sections by dotted lines. The notes of these sections appear in the *form of field book* § 266 and an isometric view is shown in Figure 147.

As an aid in finding the points where the grade line crosses the roadbed both on the sides and at the center, the following method is sometimes used (Fig. 145).

Suppose the cut at station A is d_1 and the fill at C is d_2 . If the ground slopes uniformly between A and C , the change in elevation will be $(d_1 + d_2)$. From B draw the line BG parallel

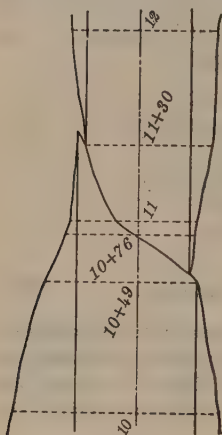


FIG. 143.

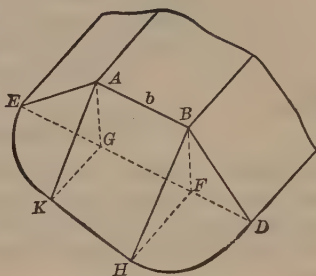


FIG. 144.

to the grade line CF . Then, from the similar triangles BED and BGA ,

$$DF = x = \frac{ld_1}{d_1 + d_2}$$

A similar scheme may be used for the side points. The

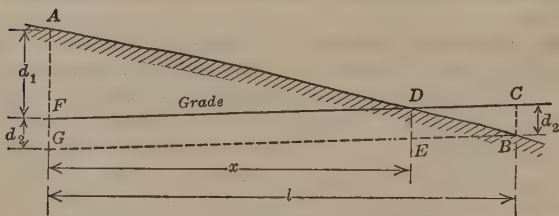


FIG. 145.

final test is that the actual rod reading at D and the computed grade rod must agree.

When an embankment ends at a *trestle*, the material takes its natural slope at the ends as well as at the sides (Fig. 144).

ABDE is the last cross section, but end stakes are to be set at *H* and *K* to define the end sections taken parallel to the center line. The amount of material in the terminal wedge and quarter-cones may then be computed and added to the rest of the earthwork.

OTHER FIELD METHODS

264. By equation based on ground slope. When the transverse slope is quite regular within the limits of the section, its slope ratio s' may be ascertained and used to find approximately the distance to the required slope stake. This done in advance will save several trial computations on the way in case of a deep section, by whatever method the section may be staked out. For this purpose, find the depth BF at the edge of the base; then, in Fig. 138,

$$BH = sh = s'(h - BF)$$

from which

$$h = \frac{s'}{s' - s} BF$$

and this, in equation 273, gives

$$x = \frac{1}{2}b + \frac{ss'}{s' - s} BF \quad (275)$$

which applies to the *deep side* in either cuts or fills.

Similarly, for the *shallow side*,

$$x = \frac{1}{2}b + \frac{ss'}{s' + s} AL \quad (276)$$

265. By use of the automatic rod and tape. In this method a specially constructed rod and a tape are necessary.

Tape. "Take any linen tape graduated in feet and tenths, and beginning at the zero end lay off on the tape half the width of the proposed roadbed. If the roadbed is to be 20 ft wide, lay off 10 ft on the tape, then turn the tape over and on its blank side and directly opposite the 10-ft mark paint 0 with India ink. Beginning at this new 0 point make a series of

marks 1.5 tenths apart, if the side slopes of cuts are to be 1.5 to 1; but, if the side slopes are 2 to 1, make the aforesaid graduation 2 tenths apart. Next paint over each mark its proper denomination, beginning at 0 and progressing exactly as any tape is graduated. Figure 146 shows the front face of the ordinary engineer's linen tape and the rear face of the same tape graduated as just described. The graduations need be carried out only as far as the probable distance of any slope stake from the base line."

Rod. The rod is 10 ft long, shod at both ends as is an ordinary level rod, and dressed so as to leave a bead on each

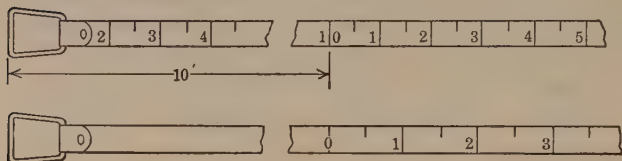


FIG. 146.

side. A movable endless tape passes around the rod and is graduated in feet and tenths from 0 to 20 ft, the numbers extending progressively up the face of the rod. The 0 and 20 coincide and are fastened together. Some form of index mark may be used to tell when the zero is at the bottom of the rod. A tape made of flexible steel will be more lasting than one made of interwoven material such as that in a cloth tape.

Method of use. The fundamental principle in the use of the automatic rod and tape here described is exactly the same as that previously described where slope stakes are set using the "grade rod" as reference.

As there noted, the grade rod is the difference between the height of instrument and the grade elevation. This simply means that, if the rod reading were equal to the grade rod, the bottom of the rod would be on grade, and there would be no cut or fill.

First, take the case where the H.I. is above the grade elevation and in cut. Change the tape on the front of "automatic rod" so that the reading will correspond to the grade

rod for the particular setup of the instrument and the station in question. For instance, in a cut, suppose the grade rod is 9.4 and the rod reading at center is 6.4. The cut will then be $9.4 - 6.4 = 3.0$. If the 9.4 reading on the rod is moved so that it coincides with the line of collimation for the setup of the instrument, the grade elevation will be found 9.4 ft below this line. In this particular example the H.I. is 9.4 ft above the grade elevation, and the rod when held at the center is 6.0 above the grade, and, since the tape on the rod was set at 9.0, the rod reading would be 3.0 which is the center cut.

To find the slope stake, move the rod to a point where it is estimated the slope stake should be, and take a reading. If this agrees with the reading on the automatic tape, the point is correct, but, if otherwise, move the rod nearer or farther from the center so that there is an agreement between rod reading and tape reading.

In case of fill, the normal rod reading is larger than the grade rod. An example will illustrate the change from the work in cut. Suppose the grade rod is 5.0 and the center fill 4.0. The rod reading at the center would be the sum of the two or 9.0. The tape on the automatic rod should be set so that, if the rod were held at the grade elevation, the reading would be 5.0 and, when the rod is held at the center point of the station in question, the reading would be 9.0. Move the tape to accomplish this.

It is to be here noted that different tapes must be used for cut and for fill, each with zero starting at the particular $\frac{1}{2}b$.

Second. Where the H.I. is below grade (only possible in fill) the grade rod is numerically negative, and the tape on the level rod is *lowered* by the value of the grade rod. Otherwise the method of procedure is the same as when H.I. is above the grade.

266. Form of field book. A complete record of all cross-section work is kept in the cross-section book. On the left-hand page are recorded, in the *first column*, the numbers of the stations and other points where sections are taken; *in the second*, the $+$ sights (or *B.S's*); *in the third*, the height of instrument (H.I.); *in the fourth*, the $-$ sights (or *F.S's*); *in the fifth*, the elevations of the stations; and *in the sixth*, the eleva-

tion of the grade for the same points. Sometimes a new line of levels is carried along with the slope staking, but, if the location levels are carefully checked, this is sometimes considered unnecessary. The above form provides for either method. The grade rod may be inserted in some convenient place, in the *second column* with a *parenthesis*. A record should also be made of the slope ratio s and the width of the base b . The right-hand page has a central column, in which, and opposite

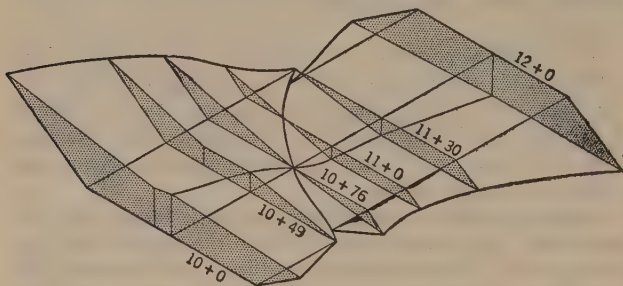


FIG. 147.

the number of the station, is recorded the center depth of the section, marked $+$ for cut or $-$ for fill, to indicate cut or fill, as the case may require. To the right of this are recorded the notes of that portion of the section which lies on the right of the center line, as the line was run, and to the left, the notes of the left side. The distance from the center to each point noted is recorded as the numerator of a fraction, and the cut or fill at the point as the denominator prefixed by a $+$ or $-$, as the case may require. The denominator for a grade point is zero. The several points are noted in order as they occur from the center outwards; the notes farthest from the center of the page usually appertain to the slope stakes; but in case the cross profile is extended beyond the slope stake, the note of the latter should be surrounded by a circle to distinguish it. The following form is a specimen of a right-hand page, with the first column only of the left-hand page. It is the notes for Figures 143 and 147.

Sta.	L.		C.	R.
12+0		$\frac{13.0}{-4.0}$	$\frac{0}{-3.4}$	$\frac{12.1}{-3.4}$
+30	$\frac{8.0}{0}$	$\frac{7.5}{-0.3}$	$\frac{0}{-1.5}$	$\frac{9.8}{-1.9}$
11+0	$\frac{10.2}{+1.5}$	$\frac{4.7}{0}$	$\frac{0}{-1.1}$	$\frac{8.5}{-1.0}$
+76		$\frac{12.5}{+3.0}$	$\frac{0}{0}$	$\frac{8.8}{-1.2}$
+49	$\frac{14.3}{+4.2}$	$\frac{4.3}{+1.5}$	$\frac{0}{+1.6}$	$\frac{8.0}{0}$
10+0	$\frac{16.7}{+5.8}$	$\frac{1.5}{+3.2}$	$\frac{0}{+3.5}$	$\frac{13.6}{+3.7}$

CHAPTER XI

CALCULATION OF EARTHWORK

267. The principles involved.

A **prismoid** is a solid having plane parallel bases or ends, and bounded on the sides either by planes, or by such surfaces as may be generated by a right line moving continuously along the edges of the bases as directrices. The bases do not need the *same number of sides*.

Wedges and **pyramids** are special forms of prismoids.

Except for minor ground irregularities which tend to cancel each other, the solid between two consecutive cross sections on a tangent is usually a prismoid, the cross sections forming the two bases, and the ground surface and the surface of the earthwork forming the sides.

The volume of any prismoid can be precisely computed by the **prismoidal formula**, § 275. As the prismoidal formula is somewhat awkward to use, an approximate formula called the **mean-area formula** or the **end-area formula** is usually employed, § 275. Both formulas are based on the dimensions of the cross sections and the distances between them. On curves the volumes are first computed as for straight alignment and then corrected according to § 278.

The positions of the cross sections must have been so selected that the solid included between any two consecutive sections may be a prismoid as nearly as possible. On a tangent the roadbed and side slopes are planes, so that the prismoidal character of a given solid depends on the shape of the natural surface. When the natural surface is a plane, the sections are taken only at the regular stations, 100 ft apart. When it is curved, warped, irregular, or broken, the sections must be more numerous, so that the surface limited by any two shall be composed substantially of right-lined elements extending from one section to the other.

If two end sections of a prismoid are somewhat similar, we infer that the corresponding points are connected by right-lined elements, forming in each case the axis of a ridge or of a hollow. If one section has less breaks than the next, some of these ridges or hollows must vanish; and, in order that the solid may be a prismoid, they must vanish in the section of least breaks; therefore, a cross section must be taken on the ground through the point where each ridge or hollow vanishes, and the distance of that point from the center line noted, so that it may be coupled with the proper point in the next section for exact calculation of content.

When ridges or hollows run diagonally across the line of road, cross sections must be taken where they are intersected not only by the center line, but also by the side slopes; that is, sections must be taken so that a side stake may stand on top of each ridge and at the bottom of each hollow. In case the center line intersects at right angles a retaining wall or other vertical surface, two cross sections are required at the same point, one at top and the other at base of wall, in order to furnish the data necessary for calculating the content each way from the vertical surface. (See Chapter X.)

Every thorough cut terminates in a sidehill cutting, a pyramid, or a wedge; the last happens only when the contour of the natural surface is at right angles to the line of road. Sections should always be taken through the points where the edges of the roadbed meet the surface, as these are the points of separation between thorough and sidehill work. An illustration of such a case is given in Fig. 147. This sketch conforms to the notes taken in § 266. In sidehill work the foregoing rules apply as well, but sections will generally be more numerous than in thorough cuts. The same rules apply also to embankment, but, as grading is preferably paid for in excavation, the same precision in determining the quantities in embankment is not usually necessary.

268. Methods of computing the areas of cross sections.

It is evident that the first step in computing the volumes is to compute the areas of the cross sections. This is accomplished by one of the following methods:

1. **By dividing the cross section into triangles.** There are several methods of arranging the triangles. The dimensions of the triangles are usually scaled from the plotted cross sec-

tions. If the sections were taken during the process of slope staking, the field notes can be used directly without necessarily plotting the cross sections. The use of triangles is fully described in this chapter.

2. **By stripping.** This method is especially applicable to the wide shallow sections found in highway earthwork. To compute the area by stripping proceed as follows (Fig. 148):

Divide the plotted cross section by a series of equally spaced vertical lines, 2 to 8 ft apart. Measure the height of the



FIG. 148.

center line of each vertical strip. Find the sum of these heights in feet, and multiply by the width of one section to obtain the area.

This can best be accomplished as follows: Prepare a long strip of paper about $\frac{1}{2}$ in. wide. Make a pencil mark at the edge near one end. Place the paper so that the edge lies along the center line of the first strip with the pencil mark even with the lower end of the center line (position *a*). Mark the strip of paper at the upper end of the center line. Move the strip of paper so that the second mark coincides with the lower end of the second center line (position *b*). Mark the paper at the upper end of the second center line. Continue this process until the length of the sum of all the center lines has been marked off. This length is then placed on a scale which has been previously laid out (usually on the cross-section paper) so that it reads directly in square feet according to the width selected for the vertical sections.

3. **By planimeter.** Areas of cross sections are often determined by planimeter for *estimates* or for *checking* areas determined by other methods. The instrument should never be employed alone for results to be used as a basis for payment.

269. Formulas for sectional areas.

Let b = base of section or width of roadbed

$$s = \text{slope ratio} = \frac{\text{horizontal}}{\text{vertical}}$$

d = depth at center stake

h, k = depths at side stakes

m, n = horizontal distances from center to side stakes

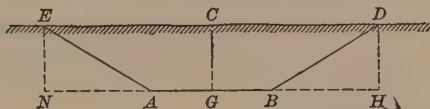


FIG. 149.

For ground level transversely, the section is a trapezoid and the area is (Fig. 149):

$$A = bd + sd^2 \quad (277)$$

or, directly from the field notes,

$$A = \frac{1}{2}(b + m + n)d \quad (278)$$

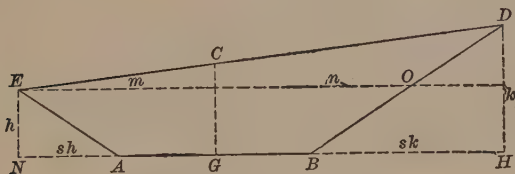


FIG. 150.

For ground of uniform transverse slope between slope stakes (Fig. 150) the section consists of the trapezoid ABOE and the triangle EOD. Hence,

$$A = \frac{1}{2}(AB + EO)EN + \frac{1}{2}EO(DH - EN)$$

$$A = \frac{1}{2}(AB \cdot EN + EO \cdot DH)$$

or

$$\text{Also,} \quad \begin{aligned} A &= \frac{1}{2}[bh + k(b + 2sh)] \\ A &= \frac{1}{2}[bk + h(b + 2sk)] \end{aligned} \quad (279)$$

from which, also,

$$\begin{aligned} \text{and} \quad & \left. \begin{aligned} A &= \frac{1}{2}bh + mk \\ A &= \frac{1}{2}bk + nh \end{aligned} \right\} \quad (280) \end{aligned}$$

These formulas are independent of the center depth. They are convenient for calculating the area of a plotted section having an irregular surface after the surface line has been averaged by stretching a silk thread over it. The points where the thread intersects the slope lines determine the values of h , k , m , and n , respectively.

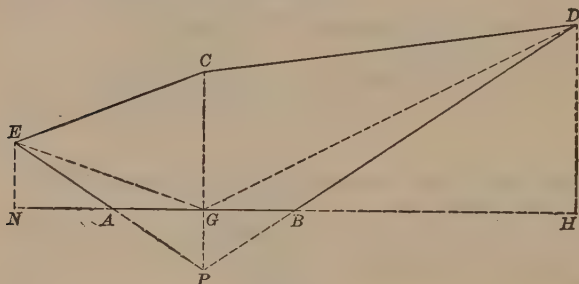


FIG. 151.

270. Three-level section (Fig. 151). If in the diagram we draw EG and DG , the section will be divided into four triangles, *two* having the common base $CG = d$ and respective heights $GN = m$ and $GH = n$, and *two* having the equal bases $AG = GB = \frac{1}{2}b$ and the respective heights $EN = h$ and $DH = k$. Hence, we have, for the area of section,

$$A = \frac{1}{2}d(m+n) + \frac{1}{4}b(h+k) \quad (281)$$

Otherwise, if the slope lines are produced to meet below grade at P , then $GP = AG/s = b/2s$. The area of $CEPD$ is $\frac{1}{2}CP \times NH = \frac{1}{2}(d + b/2s)(m+n)$. The area of ABP is $AG \times GP = b^2/4s$. Hence, we have, for the area of the section,

$$A = \frac{1}{2}\left(d + \frac{b}{2s}\right)(m+n) - \frac{b^2}{4s} \quad (282)$$

Both these formulas are convenient, and, as the values of the several letters can be substituted directly from the field notes, it is unnecessary to plot such sections.

The triangle ABP is called the *grade triangle*. Computation by equation 282 is somewhat more rapid than by equation 281, since $b/2s$ and $b^2/4s$ are constants for the same base and side slope.

271. Five-level section. Where elevations are taken at points immediately above A and B , in Fig. 151, in addition to those at C , D , and E , the section is called *five-level*. The area may be found as explained for Fig. 152.

272. Irregular section. When the surface of the ground is irregular, the plotted section may be divided into trape-

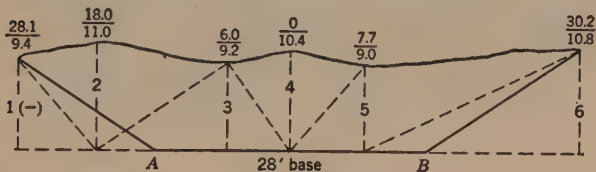


FIG. 152.

zoids by verticals drawn through the surface breaks and at the slope stakes. The area of the section is then the sum of the areas of these trapezoids less that of the two outside triangles (Fig. 152).

Or the section may be further divided into triangles, one vertical line serving as the base of two triangles which are computed in pairs. From the sum of all the areas it may or may not be necessary to deduct the area of one or both of the outside triangles. With either of these methods the dimensions used are taken directly from the field notes, and many times it is not necessary to plot the section.

Sometimes this method is called **cross multiplication** for the following reason. If to the original field notes (shown in the figure), a notation is added for point A and for point B and the notations are listed clockwise around the figure beginning with point A , there results

$$\frac{14}{0} \times \frac{28.1}{9.4} \times \frac{18.0}{11.0} \times \frac{6.0}{9.2} \times \frac{0}{10.4} \times \frac{7.7}{9.0} \times \frac{30.2}{10.8} \times \frac{14}{0}$$

From this it is possible to make the computation by the following rule. Multiply each denominator by the difference

of the two adjacent numerators, always subtracting the numerator which is nearest, in position on the list, to the numerator zero. The two numerators adjacent to zero must be added. The algebraic sum of these products divided by 2 is the area. For example, designating each triangle by the number given on its altitude in the figure, the area is computed as follows:

Triangle:

1	$9.4(14.0 - 18.0) = 9.4(-4.0) = -37.6$
2	$11.0(28.1 - 6.0) = 11.0(22.1) = +243.1$
3	$9.2(18.0 - 0) = 9.2(18.0) = +165.6$
4	$10.4(6.0 + 7.7) = 10.4(13.7) = +142.5$
5 *	$9.0(30.2 - 0) = 9.0(30.2) = +271.8$
6	$10.8(14 - 7.7) = 10.8(6.3) = +68.0$
	853.4
	$\div 2 = 426.7$

But when the breaks are numerous the number of parts to be calculated may be greatly reduced by the use of one or more averaging lines stretched over the surface line of the plotted section and noting the points where they intersect the center line and the side lines. Such points then govern the section in place of the original notes, and the section is thus graphically reduced to a two-level or three-level section, as the case may require, with the same ultimate results in area or solidity.

273. Sidehill sections. *In sidehill work*, the section may also be divided into triangles and the area found as with irregular sections.

274. Valuation work. In work on state or Federal valuation of existing railways, it is often necessary to estimate volumes where the original profiles and notes of the cross section have been either lost or destroyed. Under such conditions, the side heights h and k , together with the width of roadbed b , and the slope ratio s , are obtained from direct

* Triangle 5 is best visualized if one assumes two triangles of which line 5 is the common base. Their combined areas would then be the sum of their altitudes 30.2, multiplied by their common base 9.0 (and later divided by two).

measurements in the field. No information as to the condition of the original surface is available, and, consequently, it is considered as sloping uniformly between slope stakes. When the existing roadbed is level, equations 279 or 280 will apply. If the roadbed is not level transversely, the most satisfactory method is to use a level line at the top of rail or at the top of tie as a reference line. The area between this level line and the line joining the slope stakes may then be found, and the resultant area obtained by adding or subtracting the proper amounts for subgrade level.

275. Volumes of solids. The volume of a solid may be found either by the *mean-area formula* or by the *prismoidal formula*. The former does not, in general, give the true volume, whereas the latter does.

The mean-area formula is

$$S = \frac{l}{27} \frac{(A + A')}{2} \text{(in cu yd)} \quad (283)$$

where S = the volume in cubic yards between two adjacent sections, l = the length in feet, A and A' = the areas at the two parallel ends in sq ft.

Equation 283 may also be expressed as

$$S = \frac{A}{27} \frac{l}{2} + \frac{A'}{27} \frac{l}{2}$$

This is based on the assumption that each area extends a distance of $\frac{1}{2}l$.

Equation 283, when applied to a series of equally spaced cross sections, can be written as follows:

$$S = \frac{l}{27} \left(\frac{A_1}{2} + A_2 + \cdots + A_{(n-1)} + \frac{A_n}{2} \right)$$

This indicates that the result of applying the mean-area formula to successive stations will give a value equivalent to that which would occur if each area continued unchanged in each direction halfway towards the next station.

When the length between adjacent cross sections is less than the standard distance, the mean-area volume can be obtained

by multiplying each area by the sum of half the distances to the adjacent sections.

For example, if a fill extended from a flat bridge abutment at station 20 to a flat bridge abutment at station 25, and the

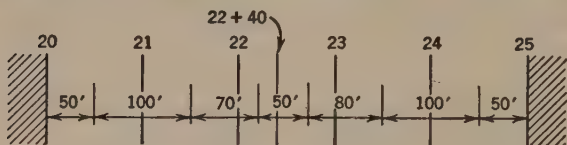


FIG. 153.

sections and their locations were as given below, the resulting volume computation would be the following (Fig. 153):

Area, sq ft	Station	Computation of cu yd
200	20	$200 \times 50 \div 27$
300	21	$300 \times 100 \div 27$
250	22	$250 \times 70 \div 27$
500	22 + 40	$500 \times 50 \div 27$
350	23	$350 \times 80 \div 27$
220	24	$220 \times 100 \div 27$
200	25	$200 \times 50 \div 27$

The *prismoidal formula* is

$$S = \frac{l}{6 \times 27} (A + 4M + A') \text{ (in cu yd)} \quad (284)$$

where M = the area of a section midway between the ends, and the others are as before. This area is not a mean of the other two, but the linear dimensions of the mid-section are means of the corresponding dimensions of the end sections; from which, therefore, the area of the mid-section may be computed.

Computation of volumes. The labor of calculating the prismoidal volumes may, in most instances, be lessened by first using equation 283 and then applying a correction, called the **prismoidal correction**. The result will be the same as if equation 284 were used. These correction formulas will now be found.

276. Prismoidal correction formulas. Let C = the difference between results in computing the contents of a solid by mean areas and by the prismoidal formula.

Then,

$$C = S_E - S_P \quad (285)$$

where

S_E = the mean area volume

and

S_P = the prismoidal volume

Subtracting equation 284 from equation 283 yields

$$C = \frac{l}{3 \times 27} (A - 2M + A') \quad (286)$$

which is the general formula for the prismoidal correction.

Equation 286 should never be applied to equation 283 in the form given, but its modifications, equations 287 and 289, are used.

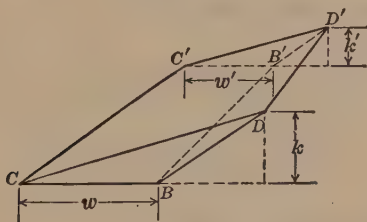


FIG. 154.

Triangular section (Fig. 154). When the bases of a solid are triangles, $A = \frac{1}{2}wk$; $A' = \frac{1}{2}w'k'$; and

$$M = \frac{1}{2} \left[\left(\frac{w+w'}{2} \right) \left(\frac{k+k'}{2} \right) \right]$$

Substituting these quantities in equation 286 and collecting terms give

$$C = \frac{l}{12 \times 27} (w-w')(k-k') \quad (287)$$

This formula might be called the *basic* one for *prismoidal corrections*.

The prismoidal volume may in this case be obtained directly from equation 284 rather than by use of equations 283 and 287. By substituting in equation 284 the values of A , A' , and M just found, and collecting terms, we get

$$S_p = \frac{l}{12 \times 27} [(2w + w')k + (2w' + w)k']$$

Three-level section. A solid whose bases are three-level sections may be divided into triangular prisms, and the mean-area volume of each prism found. For the prismoidal corrections, equation 287 may be applied to each triangular prism.

In Fig. 151, the correction for the triangular prisms between AGE , BGD and similar triangles at the second station will be zero, since w and w' are equal. The correction for the two triangular prisms bounded by GEC , GDC and similar triangles at the second station will be

$$\frac{l}{12 \times 27} (d - d')(n - n')$$

and

$$\frac{l}{12 \times 27} (d - d')(m - m')$$

or, for the part $EGDC$, it will be

$$C = \frac{l}{12 \times 27} (d - d')[(m + n) - (m' + n')] \quad (288)$$

If $(m + n)$ is designated by D , and $(m + n')$ by D' this becomes

$$C = \frac{l}{12 \times 27} (d - d')(D - D') \quad (289)$$

Again by substituting the values of A , A' , and M from equation 282 in equation 286, the same result could be obtained.

When C as found from equation 289 is positive, it signifies that S_E is larger than S_P , and *vice versa*. Equation 285 may be written $S_P = S_E - C$.

A general rule may be formulated as follows:

The prismoidal correction, *in general*, is to be subtracted from a volume computed by the *mean-area method*. The only *exception* occurs when, in the end sections, the *greater center depth is combined with a smaller distance between slope stakes*. This is a case of rare occurrence, but one which *changes the sign* of one factor in equation 289 and, therefore, of C . C is then to be added.

277. Application of the prismoidal correction. In the case of *three-level sections*, or with wedges, the data from the field notes are applied directly in equation 289.

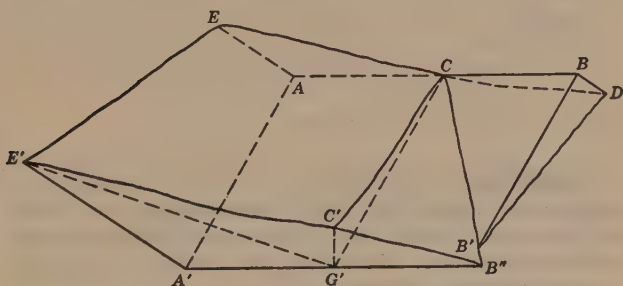


FIG. 155.

Passing from cut to fill. Figures 155 and 156 approximately illustrate part of the notes given in § 266.

The volumes between stations 10+49 and 10+76 are represented in Fig. 155. The solid $B'CBD$ is a triangular pyramid, the volume of which is equal to one third the product of the area of the base and altitude divided by 27, and the prismoidal correction is zero. The correction for the solid $A'B''C'E'EAC$, as found from equation 288, is

$$C = \frac{l}{12 \times 27} (d-0)[(m+n)-(m'+0)]$$

Sidehill work. Between stations 10+76 and 11 (Fig. 156) there is a triangular prism on the left (omitting from consideration the reading at the point 7 ft from the center) and a pris-

moid on the right. The correction for this prism is given by equation 287. The prismoidal correction for the prismoid on the right is found from equation 288, which gives

$$C = \frac{l}{12 \times 27} (0 - d') [(n + 0) - (n' + G'L')]$$

The sign of C in this equation will be positive, thus showing that the order in which the sections are taken is immaterial.

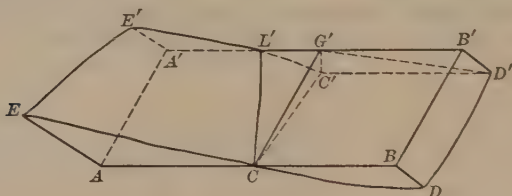


FIG. 156.

Irregular sections. The volume between two irregular sections may be found either by the prismoidal formula or by the mean-area formula. In the latter case, there are several approximate ways of determining the prismoidal correction. The two in greatest favor are:

1. When the ground is only slightly irregular, neglect the intermediate points and, for the *correction*, treat the sections as three-level.

2. Plot the sections on cross-section paper, and draw lines which will form an approximation to the three-level sections. Find d and D for each section and use equation 289.

The first method will, in general, give results sufficiently close. Personal preference governs largely the choice of other methods.

278. Correction of earthwork for curvature. The preceding calculations are based on the assumption that the center line is straight, with cross sections at right angles to it. When an excavation is on a curve, the cross sections, being in radial planes, are inclined to each other, so that the condition of a prismoid is not exactly fulfilled. But by the property of Guldinus, if any plane area is made to revolve

about an axis in the same plane, the volume of a solid generated by the area is equal to that of a prism having a base equal to the given area and a height equal to the length of path described by the center of gravity of the area. The path, being the arc of a circle, is proportional to the radius drawn to the center of gravity. If therefore a cross section is symmetrical with respect to the center line, the path of the center of gravity is equal to the measured length of the center line, and no correction for curvature is required.

But, when the ground is inclined transversely, the center of gravity is one side of the center line, and its path, if we conceive it to sweep around the curve, from one end of a prismoid to the other, is longer or shorter than the distance measured on the center line, according as the center of gravity is outside or inside the center-line curve.

Let C = correction in cubic yards due to curvature

S = cubic yards as obtained by prismoidal formula

R = radius of center line

e = eccentricity of center of gravity of section =
horizontal distance from center line to center of gravity.

We then have the proportion,

$$S \pm C : S :: R \pm e : R$$

$$C = \frac{Se}{R} \quad (290)$$

As the sections of a solid are seldom similar and equal, we shall usually have a different value of e for every section, from which, however, a mean average value may be deduced, and used in the preceding formula. But it will be more convenient to correct the areas themselves for eccentricity before finding S , which will then require no correction. For the same result will ensue whether we multiply S by e/R or one of the component factors of S by the same ratio.

If, then, c = correction of area in square feet to eccentricity, we have, at once,

$$c = \frac{Ae}{R}$$

and the corrected area equals $A \pm c$, according as the cut is deeper on the outside or inside of the curve. Each area used in determining the solid contents should, on a curve, be first corrected in this manner.

To find the value of e for any three-level section (Fig. 157).

Find the areas either side of the center line separately, calling that on the left side H and that on the right K , and take their sum and difference. Using the same notation as

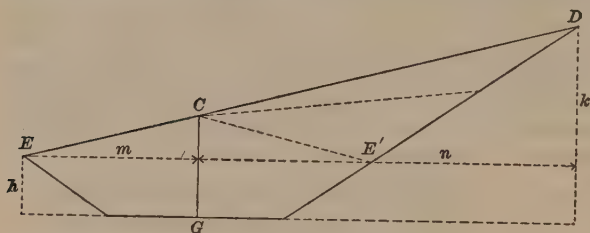


FIG. 157.

in § 269 and partially given in Fig. 157, $H = \frac{1}{2}md + \frac{1}{4}bh$, $K = \frac{1}{2}nd + \frac{1}{4}bk$, and $H + K = A$.

$$K - H = \frac{1}{2}d(n - m) + \frac{1}{4}b(k - h)$$

In the figure draw CE' equal to CE , and the triangle $CE'D$ will represent the area $(K - H)$. Bisect the side $E'D$, and draw a line from C to the middle point. Then, the center of gravity of the triangle will be on this line at two-thirds its length from C , and the horizontal distance of the center of gravity from C is $\frac{2}{3} \times \frac{1}{2}(m + n) = \frac{1}{3}(m + n)$. The center of gravity of the remainder of the section is on the center line CG , so that the value of e is found from the proportion:

$$e : \frac{1}{3}(n + m) :: K - H : A$$

$\therefore$

$$e = \frac{n + m}{3A}(K - H)$$

Hence,

$$c = \frac{Ae}{R} = \frac{n + m}{3R} \left[\frac{1}{2}d(n - m) + \frac{1}{4}b(k - h) \right] \quad (291)$$

Sections which are more irregular may be plotted and *reduced by averaging lines to three-level sections*, in order that the formula may be applied. If the ground is so irregular as to require the computation of the middle section, the correction c should be found and applied to this area (M) also before introducing it into the prismoidal formula. As the correction for curvature is always relatively small, it is usually ignored in practice for thorough cuts, except where deep cuttings with steep transverse slope occur on sharp curves.

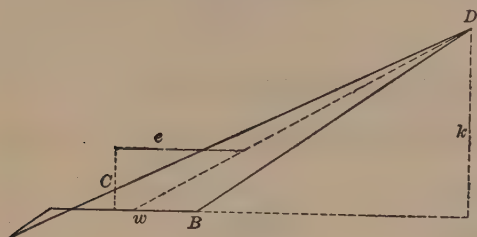


FIG. 158.

The correction is of more importance relatively in **sidehill work** as the center of gravity of the section is more remote from the center line. Let the section be reduced to a triangle by an averaging line (Fig. 158) and w be the base of the triangle formed by the averaging line. The center of gravity is at one-third the horizontal distance from the middle point of w to the side stake D , while the distance of this middle point from the center stake C is evidently $\frac{1}{2}b - \frac{1}{2}w$.

Hence,

$$e = \frac{1}{2}b - \frac{1}{2}w + \frac{1}{3}[n - (\frac{1}{2}b - \frac{1}{2}w)]$$

or

$$e = \frac{1}{3}(b + n - w)$$

and

$$c = \frac{Ae}{R} = \frac{b + n - w}{3R} \times \frac{wk}{2} \quad (292)$$

The correction c will be *plus* or *minus* as before explained. This formula applies to all sidehill triangular sections, whether there be cut or fill at the center stake.

Example 1. Thorough cut; base 20; slopes $1\frac{1}{2}:1$.

$$l = 100; \quad 8^\circ \text{ curve, left; } R = 716.78$$

Notes.

$$A \cdot \frac{16}{+4} + 12 \frac{58}{+32}$$

$$A' \cdot \frac{13}{+2} + 8 \frac{40}{+20}$$

Then,

$$K = \frac{1}{2} \times 58 \times 12 + \frac{1}{4} \times 20 \times 32 = 508$$

$$H = \frac{1}{2} \times 16 \times 12 + \frac{1}{4} \times 20 \times 4 = 116 \quad \therefore A = 624$$

$$K - H = \underline{\hspace{1cm}} 392$$

$$\text{Equation 291: } c = \frac{16+58}{3 \times 716.78} 392 = \underline{\hspace{1cm}} 13.49$$

$$(A + c) = 637.49$$

$$K' = \frac{1}{2} \times 40 \times 8 + \frac{1}{4} \times 20 \times 20 = 260$$

$$H' = \frac{1}{2} \times 13 \times 8 + \frac{1}{4} \times 20 \times 2 = 62 \quad \therefore A' = 322$$

$$K - H = \underline{\hspace{1cm}} 198$$

$$c' = \frac{13+40}{3 \times 716.78} 198 = \underline{\hspace{1cm}} 4.87$$

$$(A' + c') = 326.87$$

from which we obtain $S = 1758$ cu yd. *Ans.*

Without correction we have 1726 cu yd,

showing a difference of $\underline{\hspace{1cm}} 32$ cu yd.

Had the curve been to the *right* with same notes, c would have been *minus*, and S would = 1694.

Example 2. Sidehill cut; base 20; slopes $1\frac{1}{2}:1$.

$$l = 60; \quad 10^\circ \text{ curve, right; } R = 573.69$$

Notes.

$$\begin{array}{rcl} \frac{6}{0} & +2.8 & \frac{40}{+20} \\ & -0.8 & +\frac{2}{0.0} \quad \frac{37}{+18} \end{array}$$

$$A = \frac{1}{2}(2.8)(6+40) + \frac{10}{2}(20) = 164.4$$

$$\text{Equation 292: } c = \frac{20+40-16}{3 \times 573.69} 164.4 = \underline{4.18}$$

$$A' = \frac{1}{2} \times 8 \times 18 = \underline{72} \quad (A-c) = 160.22$$

$$c' = \frac{20+37-8}{3 \times 573.69} 72 = \underline{2.05}$$

$$(A'-c) = 69.95$$

Hence,

$$S = 250.0 \text{ cu yd}$$

$$\text{Without correction } S \text{ would} = \underline{257} \text{ cu yd}$$

$$\text{Difference} \quad \underline{7} \text{ cu yd}$$

279. Any isolated mass of rock or earth which occurs within the limits of the slope stakes, but not included in the regular notes, is separately measured and noted, so that its contents may be computed and added to the sum of the same material found in the cross sections.

This applies not only to a quantity of material of appreciable volume but also to large loose boulders. The volume of a boulder is obtained from its approximate dimensions, and, if it is one cubic yard or more, it is usually paid for as rock excavation.

280. Borrow pits. When the excavations will not suffice to complete the embankments, material may be taken from other localities, termed *borrow pits*. These should be staked out by the engineer and their contents calculated, unless the contractor is to be paid for work by embankment measurements. When material is paid for in its original position in

the borrow pit, arguments over shrinkage are avoided. A number of cross profiles are taken of the original surface, and (on the same lines) of the bottom of the pit after it is excavated, which furnish the depth of cutting at each required point. Borrow pits should be regularly excavated so that they may not present an unsightly appearance when abandoned. Borrow pits may be avoided by widening the cut uniformly at the time it is staked out, so that it may furnish sufficient material, *provided* the material is suitable, the embankment accessible, and the distance not too great. When the excavation is in excess, the surplus material should be uniformly distributed by widening the adjacent embankments, if possible; otherwise it is deposited at convenient places indicated by the engineer and is said to be *wasted*.

281. Vertical prisms. Material excavated from borrow pits may be measured also by first staking off the field into rectangles of suitable size and taking the elevation of surface at every stake. If convenient, some triangles may be laid out where boundaries are oblique. All lines should be carefully referenced. After excavation, the intersections are re-located and their elevations taken, the difference in elevation being the depth of cut at each point. Thus, the entire mass

is subdivided into vertical prisms, truncated or otherwise, the cubic contents of which may be easily computed. To facilitate the reduction to cubic yards it is customary to choose such dimensions as will make the area of each prism base some multiple of 27 sq ft.

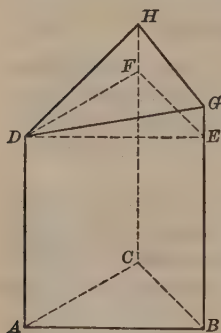


FIG. 159.

The proper size of rectangle to be used depends on the natural surface which should give practically right lines to prism ends. Shallow work calls for larger rectangles because so soon excavated.

282. *To find the volume of a truncated triangular prism, whose horizontal section is a triangle of given area A (Fig. 159).*

Let h_1 , h_2 , and h_3 denote the heights AD , BG , and CH . Through the lowest point D of the upper face, draw a

horizontal plane DEF , cutting off the pyramid $DEGHF$, whose base is a trapezoid, and whose altitude is the perpendicular distance from D to FE and designated by a .

The volume of the pyramid $DEGHF$,

$$\frac{1}{3}a \times FEH = \frac{1}{3}a \times \frac{1}{2}(EG+FH)FE = \frac{1}{3}A(EG+FH)$$

since

$$\frac{1}{2}a \times FE = A$$

By geometry, the volume of a prism, not truncated = $Ah = Ah_1$ in this case. The volume of the truncated prism $ABCDGH$ = the sum of the two parts

$$= Ah_1 + \frac{1}{3}A(EG+FH)$$

$$= A \times \frac{1}{3}[h_1 + (h_1+EG) + (h_1+FH)]$$

or, in cubic yards,

$$S = \frac{A}{27} \frac{h_1+h_2+h_3}{3} \quad (293)$$

283. To find the volume of a truncated rectangular prism, whose horizontal section is a rectangle of area A (Fig. 160).

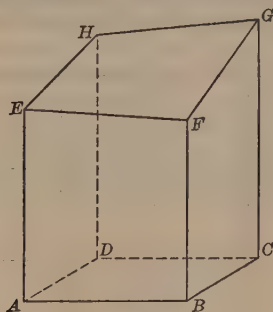


FIG. 160.

The **end-area formula** gives the *correct* cubic content, since in this figure the *prismoidal correction* is zero, provided that the top and bottom ends, whether plane or warped, are bounded by right lines.

Let the heights AE , BF , CG , and DH be represented by h_1 , h_2 , h_3 and h_4 , and the area $ABCD$ by A .

Now the figures $ADHE$ and $BCGF$ may be considered as bases of the solid with the altitude as $AB = DC$.

The mean-area volume:

$$\begin{aligned}
 S &= \frac{AB (\text{area } ADHE + \text{area } BCGF)}{2 \times 27} \\
 &= \frac{1}{2} \cdot \frac{AB}{27} \left[\left(\frac{h_1 + h_4}{2} \right) AD + \left(\frac{h_2 + h_3}{2} \right) BC \right] \\
 &= \frac{1}{4} \cdot \frac{AB}{27} (h_1 + h_2 + h_3 + h_4) BC
 \end{aligned}$$

but

$$AB \times BC = A$$

$\therefore$

$$S = \frac{A}{27} \left(\frac{h_1 + h_2 + h_3 + h_4}{4} \right) \quad (294)$$

284. Method by unit areas. When a number of prisms contiguous to each other have the same horizontal section A , their total cubic content may be obtained by a single formula. For, since by equation 294 the four-corner depths of a prism are to be added together, it is evident that the depth at any

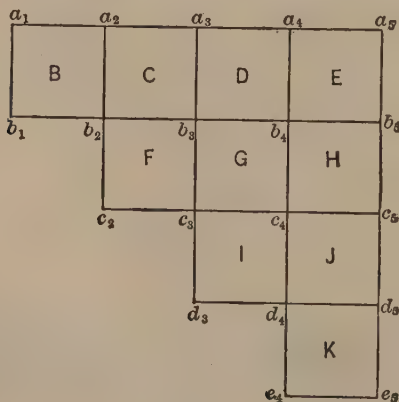


FIG. 161.

corner whatever will be taken into account as many times as the number of rectangles which meet at that point.

Thus, in Fig. 161 the depths at the corners a_1, b_1, c_2, d_3 , etc., enter into the volume of one prism only; whereas those at a_2, a_3, a_4 , etc., affect two prisms each; and those at b_2, c_3, d_4 , etc., affect three prisms each, and so on.

Therefore, if we let s_1 = the sum of all depths used but once, s_2 = the sum of all depths used twice, s_3 = the sum of all depths used three times, and s_4 = the sum of all depths used four times, we shall have, for the total content of all prisms considered,

$$S_{\text{total}} = A \frac{s_1 + 2s_2 + 3s_3 + 4s_4}{4 \times 27} \quad (295)$$

Marginal masses, not included in this system, must be measured and computed separately.

285. The foregoing method of prisms is not well adapted to steep hillsides or bluff banks from which material is to be borrowed. In such cases, if the pit is apart from the road, a base line is staked out in the general direction of the contour, and frequent cross sections are taken to define the shape of the pit before and after excavation.

If the needed material is to be taken from the regular cuts, the regular cross sections are extended beyond the slope stakes, other stakes are set to mark the limit of the pit, and the quantities are computed in the usual manner.

But, if the roadbed consists of a long shallow embankment made of *material scraped up at random from either side*, the quantities should be *measured and paid for in the finished fill*, under the terms of the contract, without reference to the borrow pits.

CHAPTER XII

EARTHWORK TABLES

286. The labor involved in the calculation of earthwork may be greatly reduced by the use of earthwork tables.

The common forms of tables are those for level sections, three-level sections, triangular prisms, and prismatical corrections.

287. Level sections. For purposes of preliminary estimates, tables computed on the assumption that the ground is level transversely are quite sufficient. The volume of any one solid may be greatly in error, but it is surprising how nearly the *total* of the preliminary volumes on an extended line will compare with the *final volumes* obtained after cross-sectioning. The center cut or fill is taken from the profile.

The area of a level section is expressed by equation 277 which is

$$A = bd + sd^2$$

The volume in cubic yards for a length of 100 ft is

$$S = \frac{100}{27}(bd + sd^2) \quad (296)$$

Table XXX was computed by this formula with such values of b and s as are in common use.

A section affects the volumes for 50 ft each side of itself. For preliminary estimates, the volumes may remain as taken from the table, in which case, where there are whole stations, the volume extends from plus 50 to plus 50. In the construction of the mass diagram (see Chapter XIV) the volume for a 50-ft length should be added to that for a preceding 50-ft length, and again to a succeeding 50-ft length, in order to give the amounts between adjacent whole stations. For sub-stations the proper percentage is taken.

288. Tables of triangular prisms. The volume of a triangular prism is equal to the product of the area of the base and the altitude, or

$$S = \frac{wal}{2 \times 27} \text{ cu yd} \quad (297)$$

where w and a are the base and altitude of the triangular section, and l is the altitude of the prism.

For a 50-ft length this equation becomes

$$S = \frac{50}{54} wa \quad (298)$$

Table XXXI has been computed from equation 298 for different values of w and a . In this table w is considered as "width" and a as "height," but these terms may be used interchangeably when convenient, since the product is the same.

The volume of any solid which can be divided into triangular prisms may be found from this table.

289. Tables of three-level sections. The area of a three-level section may be found by the two methods given in § 270. In the first method the section is divided into four triangles. The volume in cubic yards for prisms of length 50 ft will be

$$S_E = \frac{50}{54} d(m+n) + \frac{50}{54} \frac{1}{2} b(h+k) \quad (299)$$

It is to be noted that the terms on the right-hand side of this equation are similar to equation 298 for the volume of a triangular prism. Consequently Table XXXI may be used for the products of the parts and the constant $\frac{50}{54}$.

In the second method of § 270, the area is made up of two triangles minus the grade triangle. The volume for length 50 will be

$$S_E = \frac{50}{54} \left(d + \frac{b}{2s} \right) (m+n) - \frac{50}{54} \frac{b^2}{2s} \quad (300)$$

Table XXXI, Triangular Prisms, is also used for this method.

Extension of level-section table. Where the center cuts and fills are taken from the profile for a preliminary estimate and the quantities obtained from Table XXX, these may be corrected by use of Table XXXI after the cross sections

have been taken, which give the side heights. These corrections are illustrated by the triangular prisms with bases DCD' and CEE' in Fig. 162. The base of each triangle is equal to $\frac{1}{2}b + sd$, and the altitudes of the triangles are the differences between the center height and each side height. If a side height is less than the center height, the correction is to be subtracted, and, if greater, added. The products of the bases and altitudes of the triangles and the constant $\frac{50}{84}$ give the correct volumes on each side.

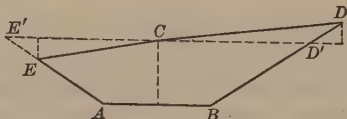


FIG. 162.

It should be noted that Table XXXI is for 50-ft lengths, whereas Table XXX is for 100-ft lengths.

290. Tables for irregular sections. A table of triangular prisms is suitable for finding the volumes of earthwork solids with irregular sections for bases. The sections may be divided into triangles as in Fig. 163, and the bases and altitudes of each triangle found. Equation 298 applies to each partial

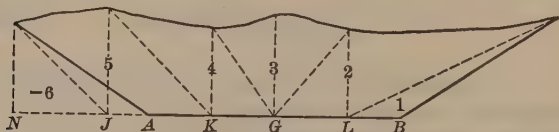


FIG. 163.

volume, and the total volume is the sum of the parts. Table XXXI is available for this work.

291. Prismoidal correction table. Where the mean-area formula is used for finding the volume of a solid, as with the tables described previously, the prismoidal correction must be applied to give the true volume. Equation 289 gives the value of this correction. For a distance between sections of 100 ft and for the result in cubic yards, this equation becomes

$$C = \frac{1}{3.24}(d-d')(D-D') \quad (301)$$

Table XXXII has been computed from this equation for different values of $(d-d')$ and $(D-D')$. The correction is applied as explained in §§ 276 and 277.

292. Example. Use of Tables XXXI and XXXII.

Notes.

$$\text{Sta. 3} \quad \frac{21.0}{+8.0} \quad +7.3 \quad \frac{19.2}{+6.8}$$

$$\text{Sta. 2} \quad \frac{17.1}{+5.4} \quad +4.5 \quad \frac{15.0}{+4.0}$$

$$b = 18, \quad s = 1\frac{1}{2} \text{ to } 1$$

The plus sign merely indicates cut and is not considered in the computations.

First, by the method based on equation 299.

For station 2,

$$d = 4.5; \quad m+n = 32.1; \quad \frac{1}{2}b = 9.0; \quad \text{and} \quad h+k = 9.4$$

From Table XXXI,

Opposite height	4.5	under 3	take	10	×	12.500	=	125.000
				2		1	×	8.333 = 8.333
				1		$\frac{1}{10}$	×	4.167 = 0.417
Opposite height	9.4			9		1	×	78.333 = 78.333

$$\text{Total volume for length of 50 ft} = 212.083$$

For station 3,

$$d = 7.3; \quad m+n = 40.2; \quad \frac{1}{2}b = 9.0; \quad \text{and} \quad h+k = 14.8$$

From Table XXXI,

Opposite height	7.3	under 4	take	10	×	27.037	=	270.370
				2		$\frac{1}{10}$	×	13.519 = 1.352
Opposite height	14.8			9		1	×	123.333 = 123.333

$$\text{Total volume for length of 50 ft} = 395.055$$

The quantities may be obtained from the tables somewhat more easily by not strictly adhering to the terms "height" and "width."

Consequently, the mean-area volume between stations 2 and 3 is

$$S_E = 212.083 + 395.055 = 607.138$$

The value of C may be found from Table XXXII, which is based on equation 301:

Now,

$$d - d' = 2.8 \quad \text{and} \quad D - D' = 8.1$$

and

$$\frac{1}{3.24} \times 2.8 \times 8.1 = 7.000$$

$\therefore$

$$S_P = S_E - C = 607.138 - 7.000 = 600.138$$

Second, by the method based on equation 300:

Now,

$$\frac{b}{2s} = 6.0$$

For station 2,

$$d + \frac{b}{2s} = 10.5 \quad \text{and} \quad m + n = 32.1$$

From Table XXXI,

Opposite height	10.5	under 3	take	10×29.167	$= 291.670$
			2	1×19.444	$= 19.444$
			1	$\frac{1}{10} \times 9.722$	$= 0.972$

Total = 312.086

For the grade triangle there is subtracted $\frac{5.0}{5.4} \times 6 \times 18 = 100$, giving the resultant volume for section at station 2 as 212.086.

For station 3,

$$d + \frac{b}{2s} = 13.3 \quad \text{and} \quad m + n = 40.2$$

From Table XXXI,

Opposite height	13.3	under 4	take	10×49.259	$= 492.590$
			2	$\frac{1}{10} \times 24.630$	$= 2.463$

Total = 495.053

The grade triangle portion (as above) = 100.

Then, the volume of the prism with base equal to the section at station 3 is 395.053.

$\therefore$ the mean-area volume of the solid between stations 2 and 3 is 607.139.

The prismoidal correction is found in the same way as in the first method and is 7.000.

$\therefore$ the prismoidal volume = $607.139 - 7.000 = 600.139$. This value is the same as that found in the first method.

The tables are carried to three decimals, thus making them more accurate when multiplied by 10. Work may be carried out to any desired degree, decimals being omitted in the final quantities.

Remark. The second method is somewhat shorter than the first, but, where $b/2s$ is not an exact decimal, the results obtained by the two will not exactly check.

CHAPTER XIII

EARTHWORK DIAGRAMS

293. General principles. An equation of the first degree containing but two variables can be graphically represented by a straight line. Equations of the second or higher degree can only be represented by curves.

Consider the equation,

$$y = ax \quad (302)$$

where a is a constant and x and y the variables. This equation is that of a straight line and is represented by Fig. 164 for a certain value of a . Various values of x are laid off on the axis of x , and the corresponding values of y are computed and laid off at right angles to OX . The line joining successive points will be represented by the line OA , which passes through the origin. Many problems can be solved from diagrams based on equation 302, among which may be mentioned that for computing acres of right of way.

Another equation is of the form,

$$y = zx \quad (303)$$

Here there are three variables, but, if we consider one as a constant, we may represent the equation graphically by substituting different values for the second variable and solve the equation for the third quantity. Figure 165 represents solutions of this equation for z of $\frac{1}{2}$, 1, and 2. When $z = \frac{1}{2}$ and $x = 1$, y will equal $\frac{1}{2}$; with $z = \frac{1}{2}$ and $x = 2$, y will equal 1, and so on. The $z = \frac{1}{2}$ line is thus found by laying off the quantities x and y along and at right angles to the axis of X . Cross-section paper may be used to advantage in work of this nature.

Other common equations are of the form,

$$y = axx \quad (304)$$

$$y = a(z+b)(x+c)k \quad (305)$$

where a , b , c and k are constants. Diagrams for equations in form similar to both these may be plotted as shown in Fig. 165.

Nearly all the equations for the computation of earthwork are similar in form to the last three equations.

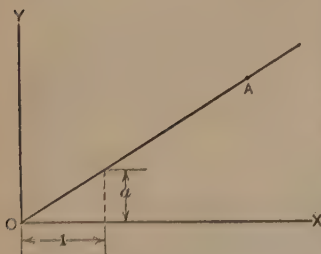


FIG. 164.

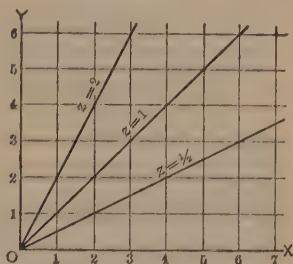


FIG. 165.

294. Triangular prisms. The volume in cubic yards of a triangular prism of length 50 ft is $\frac{5.9}{54}wa$, where w and a represent the base and altitude of the triangular section. A diagram may be constructed for solving this equation. Different values of w and a may be substituted, giving corresponding volumes.

The following table will be of assistance in plotting the diagram. The particular values chosen for w were taken for simplicity in computing and plotting.

TABLE FOR PLOTTING PLATE I. TRIANGULAR PRISMS

VALUES OF w

		0	5.4	10.8	16.2	21.6	27.0
Values of a	0	0	0	0	0	0	0
	1	0	5	10	15	20	25
	2	0	10	20	30	40	50
	3	0	15	30	45	60	75
	4	0	20	40	60	80	100
	5	0	25	50	75	100	125
	6	0	30	60	90	120	150
	7	0	35	70	105	140	175
	8	0	40	80	120	160	200
	9	0	45	90	135	180	225
	10	0	50	100	150	200	250

Cross-section paper may well be used for the diagram, but, since the paper is liable to be more or less inaccurate as to the ruling of the lines, several points in each line should be plotted considering the ruling of the paper as correct. The successive points are then connected.

A small reproduction of folding Plate I at the end of this volume is given in Fig. 166. Its construction is self-evident.

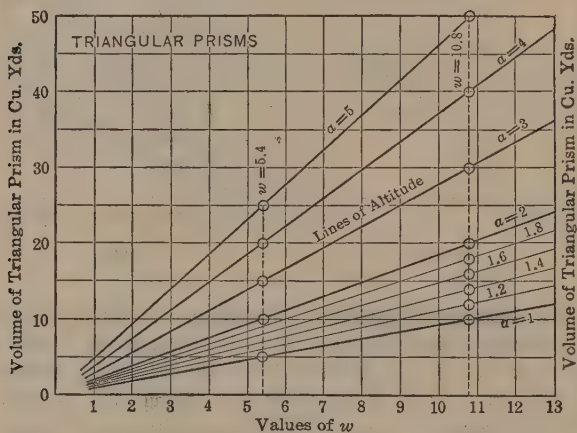


FIG. 166.

295. Use of the diagram. Let the altitude and base of a triangle be 9.0 and 12.0, respectively. To find the volume of a triangular prism of length 50 ft. Go out to the $w = 12.0$ line and up to the $a = 9.0$ line. Read the volume as 100.0 cubic yards. This quantity, as previously noted, is the product of 9.0, 12.0, and $\frac{50}{54}$.

296. Diagram for three-level sections. The mean-area volume of a solid of length 50 ft and with triangular base is found from equation 300 which with D substituted for $(m+n)$ becomes

$$S = \frac{50}{54} \left(d + \frac{b}{2s} \right) D - \frac{50}{54} \frac{b^2}{2s}$$

Since b and s are constants in any particular case, there are only three variables in this equation, d , D , and S . As previously explained, one of these values may be considered

constant, and d will be so taken. Having chosen the constant d , values of S may be found for different values of D . Here, as with triangular prisms, the work of plotting may be expedited by previously computing and arranging a table similar to the following one.

TABLE FOR PLOTTING PLATE II
DISTANCE BETWEEN SLOPE STAKES = D

Center Heights d	20.0	21.6	27.0	32.4	37.8	43.2	
	18.518	20.0	25.0	30.0	35.0	40.0	Const. Diff.
0	0	9.876	43.209	76.542	109.875	143.208	33.333
1	18.518	29.876	68.209	106.542	144.875	183.208	38.333
2	37.036	49.876	93.209	136.542	179.875	223.208	43.333
3	55.554	69.876	118.209	166.542	214.875	263.208	48.333
4	74.072	89.876	143.209	196.542	249.875	303.208	53.333
5	92.590	109.876	168.209	226.542	284.875	343.208	58.333
6	111.108	129.876	193.209	256.542	319.875	383.208	63.333
7	129.626	149.876	218.209	286.542	354.875	423.208	68.333
8	148.144	169.876	243.209	316.542	389.875	463.208	73.333
9	166.662	189.876	268.209	346.542	424.875	503.208	78.333
10	185.180	209.876	293.209	376.542	459.875	543.208	83.333

Plates II and III are plotted for bases of 20 and 16 ft, and side slopes of $1\frac{1}{2}$ to 1. A separate diagram is necessary for each different combination of b and s . Values of D are laid off on the x axis, and those for S on the y axis. Inclined lines passing through successive points will be the lines representing the different values of d .

The labor involved in preparing a table for this work may be lessened by observing that certain parts of the above equation remain constant for successive changes in the variable quantities. Proper substitutions may be made in the general formula and the constant difference in solidities found. For instance, when $d = 1$ and $D = 20$,

$$S = \frac{50}{54} \left(1 + \frac{20}{3} \right) 20 - \frac{50}{54} \frac{b^2}{2s}$$

Again when $d = 2$, and $D = 20$,

$$S' = \frac{50}{54} \left(2 + \frac{20}{3} \right) 20 - \frac{50}{54} \frac{b^2}{2s}$$

Subtracting S from S' gives

$$S' - S = \frac{50}{54} \times 20 = 18.518$$

The same difference will be found between $d = 2$, and $d = 3$.

Then if the next value of $D = 21.6$ is used with $d = 1$, and $d = 2$, the constant difference of 20 would be found.

It is advisable to solve the equation for all values of D when $d = 0$. The results are entered on the horizontal line of $d = 0$. After these quantities are found, the numbers on the other horizontal lines may be obtained by use of the various constant differences.

A check crosswise of the table may also be obtained by solving the equation for S with different values of D . For instance, when $d = 0$ and $D = 21.6$,

$$S = \frac{50}{54} \left(0 + \frac{20}{3} \right) 21.6 - \frac{50}{54} \frac{b^2}{2s}$$

with $d = 0$, and $D = 27.0$.

$$S' = \frac{50}{54} \left(0 + \frac{20}{3} \right) 27.0 - \frac{50}{54} \frac{b^2}{2s}$$

Then,

$$S' - S = \frac{50}{54} \left(\frac{20}{3} \right) (27.0 - 21.6) = 33.333$$

Similarly for the differences in volumes when $d = 1$ with $D = 21.6$ and 27.0 ,

$$S'' - S = \frac{50}{54} \left(\frac{23}{3} \right) (27.0 - 21.6) = 38.333$$

A final check on the table should be made by substituting the largest values of d and D in the formula. In this case there results

$$S = \frac{50}{54} \left(10 + \frac{20}{3} \right) 43.2 - \frac{50}{54} \frac{20^2}{3} = 543.208$$

This operation will check all quantities in the table.

Curve of level section. On both Plates II and III a curve of level section has been plotted. From equation 272 we may

find D for different values of d . Thus, for Plate II, when

$d = 0$	$D = 20.0$
$d = 0.4$	$D = 21.2$
$d = 1.4$	$D = 24.2$
$d = 2.4$	$D = 27.2$
$d = 6.4$	$D = 39.2$

The curve passing through the points having these coordinates is called the "curve of level section." The volumes for preliminary estimates may be obtained from this curve.

297. Use of the diagram. The lines and quantities on Plate II are fully designated; an example will explain the proper method of procedure in determining volumes.

Example. Cross-section notes are as follows:

Sta. 28:	$\frac{16.0}{+4.0}$	$+2.4$	$\left\{ \begin{array}{l} 11.8 \\ +1.2 \end{array} \right.$
Sta. 27:	$\frac{19.0}{+6.0}$	$+3.0$	$\left\{ \begin{array}{l} 13.6 \\ +2.4 \end{array} \right.$

For station 28, $d = 2.4$, and $D = 27.8$.

From Plate II, at the intersection of the lines $d = 2.4$ and $D = 27.8$ we obtain a volume of 110.1 cu yd.

For station 27, $d = 3.0$ and $D = 32.6$.

At the intersection of the lines $d = 3.0$ and $D = 32.6$ we find a volume of 168.3 cu yd.

Since the diagram gives results for 50-ft lengths, the total volume between the two stations is $110.1 + 168.3 = 278.4$.

The result obtained for these same notes by tables is 278.26 cu yd.

The prismoidal correction may be applied to this mean-area volume. The amount of the correction is found similarly to the way explained in the next section.

298. Diagram for prismoidal corrections. The formula for the prismoidal correction has been previously deduced and is

$$C = \frac{1}{3.24}(d-d')(D-D') \quad (301)$$

The results are in cubic yards for a distance of 100 ft between sections.

Numerical substitutions for $(d-d')$ and $(D-D')$ may be made and the corresponding results found. It will be well to take $(d-d')$ as 0, 1, 2, 3, 4, 5, etc., and to take values of $(D-D')$ so that the corresponding C will be a whole number. For instance, when $(d-d')=1$, the equation becomes $(D-D')/3.24$, and convenient values of $(D-D')$ will be 0, 3.24, 6.48, and so on, which give C the values 0, 1, 2, 3, 4, etc.

Similarly with $(d-d')$, taken as 2, 3, 4, etc. Likewise, the equations of other $(d-d')$ lines may be found, convenient substitutions of $(D-D')$ made, and a table arranged for plotting the diagram.

TABLE FOR PLOTTING PLATE IV

$d-d'$	0	3.24	6.48	9.72	12.96	16.20	19.44	22.68	25.92	$D-D'$
0	0	0	0	0	0	0	0	0	0	
1	0	1	2	3	4	5	6	7	8	
2	0	2	4	6	8	10	12	14	16	
3	0	3	6	9	12	15	18	21	24	
4	0	4	8	12	16	20	24	28	32	
5	0	5	10	15	20	25	30	35	40	
6	0	6	12	18	24	30	36	42	48	
7	0	7	14	21	28	35	42	49	56	
8	0	8	16	24	32	40	48	56	64	
9	0	9	18	27	36	45	54	63	72	
10	0	10	20	30	40	50	60	70	80	

Plate IV at the back of this volume is the diagram for "Prismoidal Corrections." Lines intermediate between whole numbers of $(d-d')$ are plotted proportionally.

For finding prismoidal corrections for irregular sections one of the methods described in § 277 may be employed, the diagram being used after the preliminary quantities have been decided on.

299. Use of the diagram. Consider as an example that $d-d' = 4.0$ and $D-D' = 11.0$.

Going out for $D-D' = 11.0$ and following up to the line of $d-d' = 4.0$ we read the correction in cubic yards as 13.6. The value of C from computation to two decimal places is 13.58. When either $D-D'$ or $d-d'$ are too large for the limits of the diagram, they may be divided by some even quantity, as 2, 3, and so on, and a corresponding multiplication made after the correction has been obtained from the diagram.

300. Conclusion. The four plates placed at the end of this volume are necessarily reproduced on a small scale. On construction work a much larger scale should be adopted. Diagrams carefully made according to the principles here given will give a high degree of precision, and their use will be conducive to speed in securing results.

The volume for any irregular section may be obtained by use of Plate I, provided the section is divided into triangles or trapezoids, as explained in the previous chapter.

CHAPTER XIV

HAUL AND THE MASS DIAGRAM

HAUL

301. Haul. The cost of removing excavated material, when the distance does not exceed a certain specified limit, is included in the price per cubic yard of the material as measured in the cuts. No payment is made for fill, as the terms of the contract require the contractor to deposit the material where directed by the engineer. But when the material must be carried beyond the specified limit, the *extra distance* is paid for at a stipulated price per cubic yard, per 100 ft. The extra distance is known by the name of *overhaul*, and is to be computed by the engineer with respect to so much of the material as is affected by it.

The contractor is entitled to the benefit of all short hauls (less than the specified limit), and material so moved should not be averaged against that which is carried beyond the limit. Therefore, no calculation of haul is made for the material from cuts which are deposited within the limiting distance.

On the other hand, on hauls greater than the specified limit, the contractor must transport the material free for the entire length of the limiting distance, and he is paid only for the product of the cubic yards multiplied by the *overhaul*.

When the overhaul is long, it is frequently cheaper to obtain fill material from borrow pits rather than from distant cuts and to waste material from cuts rather than to transport it to distant fills. Accordingly, the determination of the most economic procedure is somewhat complex. Three means of solution are available based on the following:

1. The profile and cross sections.
2. The quantity profile.
3. The mass-haul diagram.

302. Economy of earthwork from the profile and cross sections. Find on the profile of the line two points, one in excavation, and the other in embankment, such that while the distance between them equals the specified limit, the included quantities of excavation and embankment shall just balance. These points are easily found by trial, with the aid of the cross sections and calculated quantities, and become the starting points from which the haul of the remainder of the material is to be estimated.

Figure 167 represents a cut and fill in profile. The distance AB is the limit of free haul. The materials taken from AO

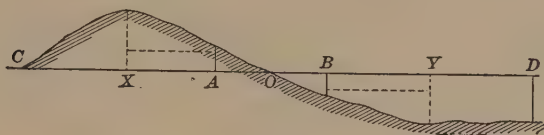


FIG. 167.

just make the fill OB and without charge for haul; but the haul of every cubic yard taken from AC and carried to the fill BD is subject to charge for the distance it is carried, less AB . It would be impossible to find the distance that each separate yard is carried, but we know from mechanics that the average distance for the entire number of yards is the distance between the centers of gravity of the cut AC and of the fill BD which is made from it. If, therefore, X and Y represent the centers of gravity, the actual average haul is the sum of the distances $(AX + BY)$, and this (expressed in stations) multiplied by the number of cubic yards in the cut AC gives the product to which the price for haul applies.

But the product of AX by the number of cubic yards in AC is equal to the sum of the products obtained by multiplying the contents of each prismoid in AC by the distance of its own center of gravity from A . The distance of the center of gravity of a prismoid from its mid-section is expressed by the formula,

$$x = \frac{l^2(A - A')}{12 \times 27S} \quad (306)$$

If we replace S by its approximate value, $\frac{l(A + A')}{2 \times 27}$, which will

produce no important error in this case, we have

$$x = \frac{l}{6} \frac{A - A'}{A + A'} \quad (307)$$

in which A should always represent the more remote end area from the starting point A , Fig. 167. Hence, x may be + or -, and it must be applied, with its proper sign, to the distance of the mid-section from the starting point A , before multiplying by the contents S . Each partial product is thus obtained.

If instead of the areas A and A' , the solidities S and S' have been taken out for uniform lengths, we may substitute S and S' for A and A' in equation 307 to find the value of x .

By a similar process with respect to the prismoids composing the mass BD , and using the point B as the starting point, we obtain finally a sum of the products representing this portion of the haul.

If a cut is divided, and parts are carried in opposite directions, the calculation of each part terminates at the dividing line. If a portion of the material in AC is wasted, it must be deducted and the haul calculated only on the remainder.

The specified limit is sometimes made as low as 100 ft, sometimes as high as 1000 ft. A limit of about 300 ft, however, is usually most convenient, as it includes the bulldozer and shaper work, while it protects the contractor on such long hauls as may occur.

303. Quantity profile. The ordinary railroad profile gives to scale all center-line depths and the relative positions of cuts and fills but does not show the quantities of material in them. The *quantity profile* is so drawn that its several areas above or below the grade line are proportional to the number of cubic yards in the several cuts and fills. To obtain this result we lay off from the grade line at each point where we have a cross section a vertical ordinate, plus or minus, representing to scale the number of cubic yards in a length of 1 ft due to that section. Connecting the extremities of the ordinates by a smooth curve we have the quantity profile. On this the center of gravity of each cut or fill is not difficult to find graphically; and equal areas, whether in cut or fill, indicate equal solidities. The quantity profile assists in a

study of the proper disposition to be made of material in the construction of the road, and in computing the distances that some materials are to be hauled.

THE MASS DIAGRAM

304. The mass-haul diagram. A mass-haul diagram or **mass diagram** is a line on a rectangular coordinate system which indicates by its ordinate the total quantity of excess excavation over fill from the beginning of the diagram up to the station that is indicated by the abscissa. When the ordinate is minus, the *fill* is in excess at that point. The diagram is usually drawn on profile paper, and it is started at the beginning of the survey line or wherever the cut and fill are balanced. It is really the integral of the quantity profile. It is best visualized by the following concept.

Imagine that the contractor had an enormous box half filled with material and having a zero mark placed at the surface of the material. He starts at the beginning of the projected railroad by excavating material to make a cut. The material excavated is put into the box, and the box is moved along as the work progresses. When a fill is reached, material is taken out of the box to make the fill. The process is continued to the end of the line, the material from the cuts being put into the box and removed to build the fills. The height of the surface of the material above the zero mark in the box at any point along the line, that is, at any plus, will then be the ordinate of a mass-haul diagram for that plus. If the surface of the material is below the zero mark, the ordinate will be minus.

305. Construction of a mass-haul diagram. A mass-haul diagram is constructed as follows (Fig. 168):

The quantities of cut or fill between each pair of adjacent cross sections is computed. If the mass-haul diagram is to be used for a trial position for a paper location, the depths of cut or fill are scaled from the grade contour, and the volumes are computed by Table XXX, Cubic Yards per 100 ft in Level Prismoids, which is based on center depths. If the diagram is to be used for other purposes, the cross section areas are usually available, and they are used to compute the quantities.

The quantity of each prismoid is listed beside the station at the end of the prismoid. Accordingly, when using the mean-area formula it is convenient to list the half stations rather than the full stations as the prismoids terminate at these points.

1	2	3		4	5	6	7
Sta.	Center <i>d</i> *	Earthwork between the Previous Cross Section and the Cross Section at the Station Listed Cu Yd		Shrink- age Added to Fills	Required Increase in Volumes of Fills	Required Volumes of Fills	Run- ning Alge- braic Totals
	Ft	Cut (+)	Fill (-)	%	Cu Yd	Cu Yd (-)	Cu Yd
0+0		0					0
1+0	+11.1	1500					+1500
2+0	-8.1		909	10	91	1000	+500
3+0	-10.9		1364	10	136	1500	-1000
4+0	+4.9	500					-500
5+0	+11.1	1500					+1000
6+0	-10.9		1364	10	136	1500	-500
7+0	-15.1		2273	10	227	2500	-3000
8+0	-8.1		909	10	91	1000	-4000
9+0	-2.3		182	10	18	200	-4200
10+0	-6.9		727	10	73	800	-5000
11+0	-8.1		909	10	91	1000	-6000
12+0	0	0					-6000
13+0	0	0					-6000
14+0	0	0					-6000
15+0	+8.3	1000					-5000

* These center depths are used only for estimates from the preliminary map. They are estimated from the grade contour at a point halfway from the previous station. This column is not used when cross-section areas are available.

The volumes are for slopes of $1\frac{1}{2}:1$ and bases 20 ft wide in cuts and 18 ft wide on fills.

FIG. 168.

The cuts and fills are listed in separate columns. Cuts are called **plus** and fills **minus**. The probable percentage required to make up the shrinkage of material used in fills is added to volumes of the fills, and the corrected volumes are listed.

Finally, the quantities of the cuts, and the fills corrected for shrinkage, are added algebraically successively. The running total is placed beside that station to which the accumulated

quantity refers. These values are plotted to form the mass-haul diagram (Fig. 169).

It is evident from the last column that, beginning in a cut, the sums increase to the end of the cut and then diminish with the following fill. So the diagram shows a *rising line* for every cut to a maximum which is opposite the grade point of the profile; thence a *falling line* indicates a fill, down to its own maximum opposite the next grade point.

Every loop of the diagram is composed of two equal parts, one of cut and the other of fill, and the number of cubic yards in each part is indicated by the length of the maximum ordinate which divides them, reckoned from any horizontal line drawn across the loop. The intersection of this line with the loop indicates the stations between which so much of the cut and its corresponding fill are located.

So the vertical distance intercepted between any two horizontal lines is the measure of the cubic yards of cutting on the rising side, or of fill on the falling side, while the longer line indicates the extreme haul, and the shorter the least haul. Projecting the ends of these lines on the profile will give the corresponding station points. The average of the horizontal lines in stations, less the number of stations of free haul, multiplied by the number of cubic yards moved, gives the product to which the price for "haul" is to be applied.

In the diagram the loops *convex* upward indicate the haul to be in one direction, whereas the loops *concave* upward indicate the haul to be in the other direction, since the movement is always from *cut to fill*, that is, *from rising line to falling line*.

When the grade line is so adjusted that cuts and fills balance, and the distances are within practicable limits, the zero line is the only line of reference needed. But borrowed material, since it appears in the diagram only as fill, depresses the diagram, whereas waste material, appearing only as cut, has the contrary effect. In such cases new equalizing lines must be drawn, parallel to the zero line and as far below or above it as will give an economical adjustment. Projecting the ends of such lines on the profile fixes the limits of borrow or waste.

The *most economical distribution* of material demands that, *in making a fill the material should be obtained:*

First, from the nearest cut.

Second, from a cut such that the cost of haul shall not exceed the cost of excavation.

Third, from a nearby borrow pit.

Borrow should not be made at one point and waste at another unless the distance is so great as to make the cost of haul prohibitive, or other conditions, such as an unbridged stream, make this course necessary.

In any case the mass diagram is a valuable aid to a satisfactory solution of the question of distribution, as well as that of haul.

306. Payment of overhaul. The following are the recommendations of the American Railway Engineering Association for all cases where an allowance for overhaul is made.

"No payment shall be made for hauling material when the length of haul does not exceed the limit of free haul, which shall be ----- feet.

"The limits of free haul shall be determined by fixing on the profile two points—one on each side of the neutral grade point—one in excavation and the other in embankment, such that the distance between them shall equal the specified free-haul limit and the included quantities of excavation and embankment balance. All the haul on material beyond this free-haul limit shall be estimated and paid for on the basis of the following method of computation, viz.:

"All material within this limit of free-haul shall be eliminated from further consideration.

"The distance between the center of gravity of the remaining mass of excavation and center of gravity of the resulting embankment, less the limit of free haul as above described, shall be the length of overhaul; and the compensation to be rendered therefor shall be determined by multiplying the yardage in the remaining mass, as above described, by the length of the overhaul. Payment for the same shall be by units of 1 cubic yard hauled one hundred (100) feet.

"Where material is obtained from borrow-pits along the embankment and runways are constructed, the haul shall be determined by the distance the team necessarily travels. The overhaul material thus hauled shall be determined by multiplying the yardage so hauled by one half the round distance made by the team less the free-haul distance. The runways shall be established by the engineer."

THE USE OF THE MASS DIAGRAM

307. Assume the following data:

Limit of free haul	500 ft
Overhaul	\$0.20 per cu yd per 100 ft
Earth excavation	\$1.00 per cu yd
Earth borrow	\$0.60 per cu yd

It is evident that it is cheaper to use an overhaul up to 300 ft than to borrow material.

In Fig. 169 a cut exists from *O* to *A*. The material can be used for the fill from *A* to *B*. At point *B*, where the line crosses the axis, the material from the cut has been exhausted. The fill from *B* to *C* will be built of the material received from *C* to *D*. The cut from *D* to *E* will be used for the fill from *E* to *F* at which point the material will be balanced. Up to the point *F* no haul is over 500 ft, and, therefore, no computation for haul is required.

Between *F* and *P* (where the quantities again balance) a long overhaul would be needed. It is necessary to determine between what points borrow should be used, how much borrow is required, and where the overhaul should start and terminate. To find the answers proceed as follows:

Find an elevation in the valley of the diagram where a horizontal line 500 ft long will just fit, line *IK*. Since *I* and *K* are at the same height on the diagram, the cut and fill between them balance, and the whole section can be handled without overhaul as its length is not over 500 ft.

Find an elevation where a horizontal line 800 ft long will just fit in the valley of the diagram, line *GL*. Material above this line requires overhaul of more than 300 ft which costs more than borrow. Accordingly, 3500 cu yd are borrowed for fill *FG*. Fill *GI*, 1500 cu yd, is built from cut *KL*.

As stated in § 306, the length of overhaul is the distance from the center of gravity of the cut to the center of gravity of the fill, minus the length of free haul. Draw a series of horizontal lines at uniform vertical intervals extending from *GI* to *HI*. They will divide *GI* into uniform increments of volume. The distance of each volume from *HI* will be measured very nearly from the line *GI* at the center of the increment to the line *HI*. The distance from *HI* to the center of

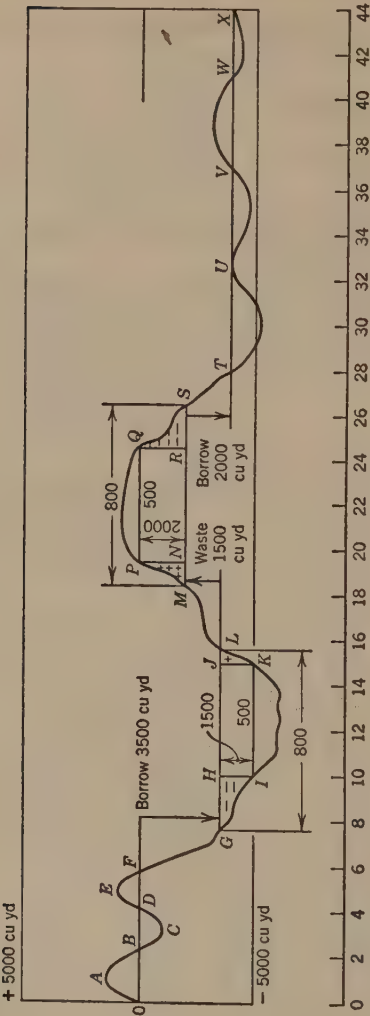


Fig. 169.

gravity of all of these volumes taken together will be the average of all these distances. The positions of the centers of gravity of the fill *GI* and the cut *KL*, thus estimated, are at stations 9+00 and 15+50, respectively. The quantity of overhaul is therefore:

$$(15.5 \text{ sta.} - 9.0 \text{ sta.} - 5.0 \text{ sta.})1500 \text{ cu yd} = 2250 \text{ cu yd sta.}$$

The next summit is treated in the same way. Overhaul is required to build the fill *QS* from the cut *MP*. The centers of gravity are at 19+0 and 25+30. The quantity of overhaul is:

$$(25.3 \text{ sta.} - 19.0 \text{ sta.} - 5.0 \text{ sta.})2000 \text{ cu yd} = 2600 \text{ cu yd sta.}$$

Material from cut *JM* would have to be hauled more than 800 ft to be used in the fill beyond *S*, so 1500 cu yd are wasted.

Next, draw *TU* just touching *U*. A line drawn higher would require more than 300 ft overhaul. 2000 cu yd are borrowed to obtain this line.

If the arrangement shown in Fig. 169 is adopted, the following schedule should be included in the contract drawings. This schedule tells the contractor where to obtain material and where to deposit it. It shows the quantities involved and the overhaul.

HAUL SCHEDULE

Present Location		Deposit Location		Quantity, cu yd	Overhaul Sta., cu yd
0+00	1+00	1+00	2+20	1500	0
3+00	4+20	2+20	3+00	1000	0
4+20	5+00	5+00	5+80	1000	0
Borrow Pit #1		5+80	7+70	3500	0
13+00	15+60	7+70	13+00	2500	2250
15+60	18+40	Waste Loc. #1		1500	0
18+40	21+00	21+00	26+50	2800	2600
Borrow Pit #2		26+50	28+00	2000	0
30+00	32+50	28+00	30+00	1300	0
35+00	37+00	32+50	35+00	800	0
37+00	39+00	39+00	41+00	900	0
41+60	44+00	41+00	41+60	400	0

CHAPTER XV

CONSTRUCTION

308. The engineering department of a railway company is usually reorganized for the construction of the road, as follows: chief engineer, division engineers, resident engineers, assistant engineers. On some roads the division engineers are styled "principal assistants"; the resident engineers are called "assistants"; and the assistant engineers are designated according to their duties, as "leveler," "rodman," and so on.

A resident engineer has charge of a few miles of line, limited to so much as he can personally superintend and direct. He has one or more assistants and an axeman in his party. All instrumental work is done and all measurements taken by the resident engineer and his assistants.

A division engineer has charge of several residencies and inspects the progress of the work on his division once or twice a week. In his office, which should be centrally located, all maps, profiles, plans, and most of the working drawings required on his division are prepared. To him the resident engineers make detailed reports once a month, or oftener if necessary, which he passes on as to their correctness, and from which he makes up a monthly report, or estimate, of the amount and value of the work done and materials provided by each contractor on his division. The estimates are forwarded about the first of each month to the chief engineer, who examines and approves them, returning for modification any that seem to require it.

The chief engineer has charge of the entire work and directs the general business of the engineering department. He occasionally inspects the work along the line.

309. Clearing and grubbing. The first step in the work of construction is to clear off all growth of timber within the limits of the right of way. The resident engineer with his

party passes over the line, making offsets to the right and left, and blazing the trees which stand on, or just within, the limits of the company's property. The blazed spot is marked with a letter *C*, as a guide to the contractor. After felling, the valuable timber should be piled near the boundary lines, to be saved as the property of the company. The brushwood is burned.

Where a deep cut is to be made, the stumps are left to be removed as the earth is excavated. In very shallow cuts and fills the contractor will generally prefer to tear up the trees by their roots at once, rather than to grub out the stumps after clearing. Where the embankments will be over 3 ft high, grubbing is not necessary; but the trees require to be *low-chopped*, leaving no stump above the roots. The engineer should indicate to the contractor the localities where each process is suitable.

310. While the clearing is in progress, the engineer should run a line of test levels touching on all the benches to verify their elevations; he may also rerun the center line, replacing any stakes that may have disappeared and setting guard plugs to any important transit points which may not have been previously guarded. If any changes in the alignment have been ordered, these may be made at the same time.

311. Cross sections. The resident engineer is furnished with a profile of the portion of the line in his charge, on which is plainly indicated by line and figures the established grade. The grade given on the profile is that which is subsequently called the subgrade, being the surface of the roadbed. The final or true grade is the upper surface of the ties after the track is laid.

The methods used in cross-sectioning are fully described in Chapter X.

The cross-section notes should be traced in ink at the first opportunity to secure their permanence. An office copy should also be made to serve in case of loss or damage to the original.

312. Shrinkage. In estimating the relative amounts of excavation and embankment required, allowance must be made for difference in the spaces occupied by the material before excavation and after it is settled in embankment. The various earths will be *more* compact in embankment,

rock less so. The difference in volume is called *shrinkage* in the one case and *increase* in the other.

The amount of shrinkage depends on the kind of material and the method of placing it in the fill. Dumped from a trestle, earth falls so loosely at first that the shrinkage is apparently greater than when the fill is made in layers hauled on by truck or scraper. A trestle fill requires several months to settle, and it is well to give it a little additional height to provide for the inevitable settlement. The slope stakes, however, are set for the true grade. The surplus height, if given at all, is made in the trestle, or is shown by poles or stakes driven at $\frac{1}{2}b$ from the center line as the fill nears completion.

But the probable shrinkage must be considered also when the grade is first established in order to provide sufficient material from the cuts, if possible, to complete the fills. When the material is paid for as measured in excavation, the quantity to be placed in the fills is computed only for the purpose of properly balancing the work.

Excess of earth allowed for shrinkage is estimated as a percentage of the quantity computed from the cross-section notes; the excess of height required to provide for shrinkage is estimated as a percentage of the height of fill. These two are not necessarily the same.

The percentages here given are from the average of general experience. They express shrinkage in volume of the several classes of materials.

Fine Sand	6%	Loam	12%
Sand and Gravel	8	Surface Soil	15
Ordinary Clay	10		

When a fill is carried up under traffic, the subsequent shrinkage will be less than half the above.

The percentage in height depends on the height as well as on the material. If P is the above tabular per cent of bulk, and p the corresponding per cent of height, then p takes the following values:

d	p	d	p
5 ft	$0.75P$	30 ft	$0.56P$
10 ft	$0.67P$	40 ft	$0.54P$
20 ft	$0.60P$	50 ft	$0.52P$

No slippery earth or quicksand should be allowed in any fill.

Rock blasted in large fragments increases its bulk about 60 per cent; in smaller fragments it increases about 75 per cent.

Embankments should be started at full width out to the slope stakes and finished at full width of the roadbed even when at a percentage above grade, as there will be both lateral and vertical shrinkage.

Example. A fill of level section, 30 ft high, is built of ordinary clay. Cubic yards per station, 6556; 10 per cent extra for shrinkage, 656 cu yd. Extra height if dumped from top, $30 \times 0.10 \times 0.56 = 1.68$ ft. Such estimates are necessarily approximate, being subject to the state of the weather, time of year, and peculiarities of the soil. Frozen embankments settle excessively when thawed out.

313. Alteration of line. Inasmuch as the center line at grade is the base of reference for all measurements and calculations in earthwork, any change made in it after the work of grading has begun should be most carefully recorded and explained. The center stakes of the old line should be left standing until after the new line is established, so that the perpendicular offset from the old line to the new, at each station, may be measured, as also the distance that the new station may be in advance of or behind the old one. The *date* of the change should be recorded. The original cross sections are extended any amount requisite, the distance out being still reckoned from the *old* center, while a marginal note states the amount by which the center has been shifted.

The difference in length of the lines will make a long or short station at the point of closing. The exact length of such a station should be recorded, so that it may be observed in retracing the line at any time, and in calculating the quantity of earthwork. The original transit notes of the altered line should be preserved, but marked as "abandoned," with a reference to the notes of the new line on another page.

314. Drains and Culverts. The engineer should examine the *nature and extent of each depression in the profile* with reference to the kind of opening required for the *passage of water*. For small springs, and for a limited surface of rainfall, pipes, in sizes varying from 12 to 24 in. diameter, serve an excel-

lent purpose as drains. These are easily laid down and, if properly bedded, with the earth tamped about them, are very permanent; but their upper surface should be at least $2\frac{1}{2}$ ft below grade. The embankment is protected at the upper end of the drain by a bit of vertical wall enclosing the end of the pipe. If necessary, a paved gutter may lead to it.

Where stone abounds, the bed of a dry ravine may be partly filled with loose stone, extending beyond the slopes a few feet, which will prevent the accumulation of water.

When the flow of water is estimated to be too great for two lines of the largest pipe, a culvert is required. A pavement is laid 1 ft thick, protected by a curb of stone or wood 3 ft deep at each end, and wide enough to allow the walls to be built on it. It should have a uniform slope, usually between the limits of 50 to 1 and 100 to 1 to ensure the ready flow of water. In firm soils the foundation pit is excavated 1 ft below the bed of the stream, but, if mud is found, this must be removed and the space filled with riprap, the upper course of which is arranged to form the pavement at the proper level. In a V-shaped ravine, requiring too much excavation at the sides, and where the fall is considerable, riprap may be used to advantage, the bed of the stream above the culvert being graded up by the same material to meet the pavement. In some cases a curtain, or cross wall, is necessary on the lower end to retain the riprap.

Culverts should be laid out at right angles to the center line whenever practicable, the bed of the stream being altered if necessary. The length of an open culvert is the entire distance between slope stakes, the walls being parallel throughout, or the length may be taken somewhat less than this, and the walls turned at right angles on the upper end, forming a facing to the foot of the slope. The walls are carried up to grade for the width of the roadbed and are stepped down to suit the slopes. A course is afterwards added to retain the ballast.

In box culverts the span varies from 2 to 5 ft, the height in the clear from 2 to 6 ft; the thickness of walls from 3 to 4 ft; the thickness of cover from 12 to 18 in., and its length is at least 2 ft greater than the span. The walls terminate in short head walls built parallel to the center line, the top course being a continuation of the cover. The length of a head wall,

measured on the outer face, is equal to the height of the culvert in the clear multiplied by the slope ratio of the embankment. The perpendicular distance from the center line to the face of a head wall is equal to one-half the roadbed, *plus* the depth of the top of the wall below grade multiplied by the slope ratio, or $\frac{1}{2}b + sk$. A coping is sometimes added.

315. Arch culverts are used when the span required is more than 5 ft, and the embankment too high to warrant carrying the walls up to grade as an open culvert. The span varies from 6 to 20 ft; the thickness of arch from 12 to 18 or 20 in. The height of abutments to the springing line varies from 2 to 10 ft, the thickness at the springing line from 3 to 5 ft, and at the base from 3 to 6 ft. The foundations are laid broader and deeper than in box culverts, each abutment having its own pit, carried to any depth found necessary. The half-length of the culvert is $\frac{1}{2}b + sk$, in which k is the depth of the crown of the arch below grade. The abutments are carried up halfway from the spring to the level of the crown of the arch, and thence sloped off toward the crown. The face walls are carried up to the crown, and coped. The wing walls stand at an angle of 30° with the axis of the culvert; they receive a batter on the face and are stepped (or sloped) down to suit the embankment. Their thickness, at the base, is the same as that of the abutment; at the outer end 3 ft. They stop about 3 ft short of the foot of the slope. They need not be curved in plan.

Any stone structure of dimensions greater than those just given scarcely comes under the head of culverts and should be made the subject of a special design by the engineer.

316. Staking out foundation pits. For box culverts. The engineer having decided on the size of culvert required makes a diagram of it in plan, on a page of his masonry book, recording all the dimensions, stating the station and *plus* at which its center is taken, the span and height of the opening, and so on. He then sets the transit at the center A , Fig. 170, measures the angle between the center line and axis (making it 90° if practicable); on the axis he lays off the distances to the ends of the culvert and drives stakes at B and C . Perpendicular to BC he lays off the half-widths of the pit, setting stakes at D and E , and laying off DF and $EH = AB$; and DG and $EI = AC$. On IG produced he lays off $CJ = CK$,

and perpendicular to this JM and KL , and finds the intersections O and N . A stake is driven at each angle, and on it is marked the cut required to reach the assumed level for the foundation. These cuts are recorded on the corresponding angles of the diagram. The pit is thus no larger than the plan of the proposed masonry, and the sides are vertical, which answers the purpose for shallow pits.

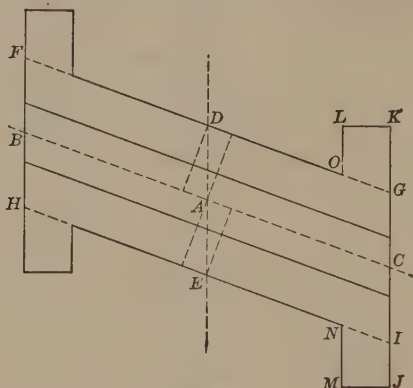


FIG. 170.

For arch culverts. The pit for each abutment when shallow may be of the same dimensions as the lower foundation course; if more than 5 ft deep, it should be enlarged by an extra space of 1 ft all around. In Fig. 171 the inside lines show the plan of the abutments at the neat lines; the outside lines represent the pits. Having prepared a plan of the structure suited to the locality and made a diagram of the same in the masonry book, set the transit at A , and drive stakes at D , E , N , and O on the center line. Then turning to the axis BC , lay off AC , and set stakes at G and I . With G as a center and a radius equal to $2DE$, describe on the ground an arc cutting EI in X or $(IX = DE \cot 30^\circ)$ may be calculated; and on XG produced lay off GK , and perpendicular to this, KL . From N lay off NP , parallel to AC , and measure PL as a check. Drive a stake at each angle, marked with the proper cutting, and record the same on the diagram. The locality may require the wings to be of different lengths and angles, of which the

engineer will judge. Guard plugs should be driven in line with the intended face of one or both abutments, so that the neat lines can be readily given when required. In case the material is not likely to stand vertically, the pit must be staked out with sloping sides, as described below.

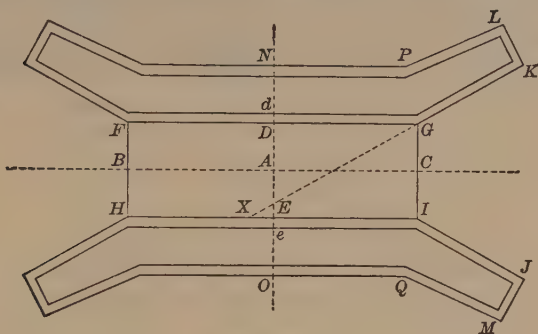


FIG. 171.

For bridge abutments. A design for every important structure is usually prepared in the office after a survey of the site. The foundation pit is then laid out from dimensions furnished on a tracing, but a diagram of the pit should

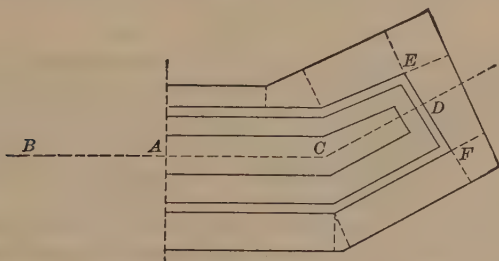


FIG. 172.

be made in the masonry book as usual. *When the bridge is on a tangent*, Fig. 172, set the transit at A on the center line at its intersection with the axis BC of the abutment *at the level of the seat*. Deflect from the tangent the angle giving the direction of BC, and lay off AC, AB, setting plugs at

The bridge chord is a line AB , midway between the chord of the curve CD , joining the centers of the abutments, and a tangent to the curve at the middle point of the span. Hence, $CA = DB = \frac{1}{2}MN$, which may be laid off, and A and B are the true centers of the abutments, from which the foundations are staked out as before.

The distance $CE = DF$ to the points where the bridge chord cuts the curve is $0.147CD$.

Should an abutment site on a curve be inaccessible, as when under water, from any transit point P on the curve, lay off PX perpendicular to the tangent at M , observing that

$$PX = MQ - AC = R(\text{vers } PM - \frac{1}{2} \text{ vers } CM)$$

and

$$AX = PQ - \frac{1}{2}AB = R(\sin PM - \frac{1}{2}CD)$$

The point A may then be found by intersection, or by direct measurement with a steel tape or wire, driving a long stout stake to show the point above the water. Other points may then be approximately found, sufficient to begin operations.

In case of a bridge of several spans, the piers are laid out in the same manner, from a center point and axis. If on a curve, each span has its own bridge chord, but for convenience the center of a pier may be taken on the center line during its construction and the bridge chord only found for the purpose of placing the bridge, the piers being long enough to allow of the shift.

To locate the centers of piers, a base line is required on one or both shores, and two transits are used to give the intersections by calculated angles. When practicable the spans should also be measured with a steel tape or wire.

The bed of a pit for any sort of structure should receive the closest scrutiny of the engineer, it being his duty to judge whether the material will resist the load to be imposed on it. A pit may require to be excavated to a greater depth than first ordered, whereas sometimes a lesser depth will answer, as when solid rock is found. When a good material is reached, if any doubt exist as to its thickness or as to the character of the underlying stratum, borings should be made or sounding rods driven down. Piles may be driven to gain the requisite firmness, and a layer of riprap, concrete, or timber

may be used to afford a uniform bearing. When satisfied of the stability of the bed, the engineer finds the original centers, and gives points for the courses of masonry. A complete record is kept of the amount and kind of excavation, the materials used in foundation under the masonry, and the size and thickness of each foundation course of masonry; the notes should be taken at the time the work is done, it being generally impossible to take measurements thereafter.

317. Cattle guards are located at highway grade crossings. They are placed at right angles across the road at the fence lines to prevent the passage of live stock. The surface guard is the form used most extensively at the present time. The material is either wood or metal.

318. Trestlework. No wooden culverts should ever be used. If stone cannot be had at first, two trestle bents may be erected, with a space between them sufficient to contain the stone structure to be built when the material for it can be brought by rail. The bents may be backed by plank to retain the embankment, and the stringers are then notched down an inch on the caps to receive the pressure of the earth and render the bents mutually sustaining. The sills are prevented from yielding to the pressure of the earth by being sunk in a trench or by sheet piling. Should the span be too long, a central bent may be used, so as not to interfere with building the wall. Sometimes pile bents may be used to greater advantage, the piles being driven in rows of four each and capped to receive the stringers. In districts where suitable stone is entirely wanting, pile or trestle abutments and piers are used for the support of bridges, the piles or posts being arranged in groups and capped to receive the direct weight of the trusses. They should not sustain the embankment, but should be connected with it by a short trestlework.

Trestlework is frequently used as a substitute for embankment, either to lessen the first cost, or to hasten the completion of the line, or for lack of suitable material with which to form an embankment. The cost of trestlework, however, is not less than that of an earth embankment formed from borrow pits, unless its height exceeds about 15 ft, depending on the relative prices of materials and labor. When not exceeding 30 ft in height, the *bents*, for single track, are

usually composed of two posts, a cap and sill, each 12×12 , and two batter posts, 10×12 , inclined at $\frac{1}{4}$ to 1, all framed together. Two lengths of 3-in. plank are spiked on diagonally at opposite sides of the bent as braces. The length of the caps should equal the width of the embankment; the posts should be 5 ft from center to center, and the batter posts 2 ft from the posts at the cap. The sill should extend about 2 ft beyond the foot of the batter post. A masonry foundation for the bent is preferable, though pile foundations are not uncommon, and some temporary structures are placed directly on a firm soil, supported only by mudsills laid crosswise under the sill. The spans, or distance between bents, may vary from 12 to 16 ft. The stringers should consist of at least four pieces, two under each rail, bolted together, with packing blocks to separate them 2 or 3 in. Over each bent and at the center of each span a piece of thick plank about 4 ft long should be placed on edge between the two pair of beams to preserve the proper distance between them, while rods pass through the beams and strain them up to the ends of the plank, to increase the stability of the beams and prevent their buckling under a load. The stringers should be able to carry safely the heaviest load without bracing against the posts. The bents, however, if high, must be braced against each other. The stringers should be continuous, the two pieces breaking joints with each other at the bents, to which they are firmly bolted. They may rest directly on the caps, or corbels may intervene. The spans on curve should be shorter than on a tangent. The ties should be notched down to fit the stringers closely, and guard rails, either wood or iron, should be secured to them firmly. Unless the spans are very short, horizontal bracing should be employed, consisting of 3-in. plank, extending from the center of each span to the ends of the caps, which are notched down to receive the plank.

For trestles much higher than 30 ft the cluster bent is preferable, so termed because each vertical post is composed of a cluster of four pieces, 8×8 or larger, standing a little apart to allow the horizontal members to pass between them. The verticals are continuous breaking joints, two and two, while the horizontals pass the posts and are bolted to them at the joints; the framing is accomplished entirely by packing blocks and bolts. The batter posts consist each of two pieces

8×8; the horizontals may be 4×10 and extend not only across the bent, but also from one bent to another. Proper bracing is also used in every direction. When very high, a secondary pair of batter posts may be introduced in the lower part of the structure. The batter need not exceed $\frac{1}{5}$ th to 1. In some instances two adjoining bents are strongly braced together, forming a tower or pier, and the piers placed from 50 to 100 ft apart, the roadway being carried on trussed bridges. The cluster bent admits of any piece being removed and a new one inserted when necessary.

Instead of the old form of *open roadway* with ties attached to stringers and stringers fastened to caps, the *solid floor* is now largely used. Here the ties rest directly in the ballast as on open line of track. The ballast is supported and held in place by planking extending from bent to bent, with pieces at sides of the roadbed to keep it from overflowing.

Steel trestles are now adopted where a permanent structure is desired. Owing to the expansion of the metal by heat, the bents cannot be continuously connected with each other as in a wooden trestle; hence, the pier form is resorted to, having spans varying from 30 to 150 ft, covered by trussed bridges, and the whole structure is more properly styled a viaduct.

319. Tunnels. Tunnels are adopted in certain cases to avoid excessive excavations, steep grades, high summits, and circuitous routes. Their disadvantages are the increased time and cost of their construction compared with an open line, and their lack of light and fresh air when in use. It is desirable that they should be on a tangent throughout, both for the admission of light and for convenience of alignment. Many tunnels, however, have been built with a curve at one or both ends or curved throughout.¹

The location of a tunnel, other things being equal, should be such as to make not only the tunnel proper, but also its immediate approaches by open cut as short as possible; and the latter should be selected so as not to be subject to overflow, nor liable to landslides. The material to be encountered may frequently be determined with tolerable accuracy by a

¹ The Mont Cenis tunnel, requiring a curve at each end, was first opened on the tangent produced, giving a straight line through, and the curves were excavated subsequently.

study of the geological formation in the vicinity, or by actual borings. The most favorable material for tunneling is a homogeneous self-supporting rock, devoid of springs, which does not disintegrate on exposure to the atmosphere. The worst materials are saturated earth and quicksand. The presence of water in any material increases the cost considerably.

The alignment of a tunnel is made the subject of special survey, after the general location is decided, and this is more or less elaborate according to the length of tunnel. A permanent station is established at the highest point crossed by the tunnel tangent, from which, if possible, monuments are set in each direction at points beyond the ends of the tunnel. If there are two principal summits, stations on these will define the tangent, which may then be produced. The monuments established beyond the tunnel should be sufficiently distant to afford a perfect backsight from the ends of the tunnel, where other monuments are also established. The first quality of instruments only should be used, and these perfectly adjusted, and the observations should be repeated many times until it is certain that all perceptible errors are eliminated. Since the line of collimation will be frequently inclined to the horizon at a considerable angle, it is important that it should revolve in a vertical plane; and to secure this a sensitive bubble tube should be attached to the horizontal axis, at right angles to the telescope of the transit. The distance may be obtained by triangulation, though direct measurement is to be preferred. A steel tape is convenient and accurate, providing that allowance be made for variations due to temperature, from an assumed standard. Carefully constructed sight rods may be used instead of plumb lines, the tape being held at right angles to them and, therefore, horizontal. A plug should be driven for each rod to stand on, and a center set to indicate the line and measurement.

As the excavation of the tunnel proceeds, the center line is given at short intervals by points on either the floor or the roof. Overhead points are generally preferred, from which short plumb lines may be hung, constantly indicating the line, with little danger of being disturbed. When a new transit point is required in the tunnel, it should be established directly under an overhead point, which serves as a check on its permanence and as a backsight when needed.

Shafts are sometimes opened to give access to several points of the tunnel at the same time, thus facilitating the work, though at an increased cost. They also serve for ventilation during the progress of the work, though they are worse than useless for this purpose afterward, except possibly in the case of a single shaft near the center of the tunnel. Some of the longest tunnels have been formed without shafts, whereas many shorter ones have had several, which have generally been closed after the tunnel was completed. Shafts are vertical, inclined, or nearly horizontal; in the last case they are called adits. Inclined shafts should make an angle of at least 60° with the vertical. Vertical shafts may be rectangular, round, or oval. Their dimensions vary, depending on their depth and the material encountered, between 8 and 25 ft. They are usually sunk on the center line of the tunnel, though sometimes at one side. When they are over the tunnel, the alignment below is obtained directly from two plumb lines of fine wire suspended on opposite sides of the shaft from points very carefully determined at the surface. The plummets are suspended in water to lessen their vibrations, and, as soon as the transit can be set up at a sufficient distance to bring the lines into focus, it is shifted by trial into exact line with the mean of their oscillations, the latter being very limited. Permanent points may then be set but should be repeatedly verified. As soon as the workings from a shaft communicate with those from either end or from another shaft, the alignment thus found is tested and revised if necessary. These operations require the greatest nicety of observation and delicacy of manipulation to obtain satisfactory results.

From plumb lines in the central shaft of the Hoosac tunnel, the line was produced 0.3 mile, and met the line produced 2.1 miles from the west end with an error in offset of $\frac{5}{16}$ in. In the Mont Cenis tunnel the lines met from opposite ends with "no appreciable" error in alignment, while the error in measurement was about 45 ft in a total length of 7.6 miles.

When a curve occurs in a tunnel, it is usually near one end. The tunnel tangent is produced and established as before described, and a second tangent from some point on the curve outside the tunnel is produced to intersect it, the intersection being precisely determined and the angle measured with many repetitions. The tangent distances are then

calculated and the position of the tangent points corrected by precise measurements, and permanent monuments are established. As the tunnel advances, points may be set at short intervals on the curve in the usual manner; but at intervals of 100 ft the regular stations should be defined with finely centered monuments, using a 100-ft steel tape carefully supported in a horizontal position. When it is necessary to use a subchord, its exact length should be calculated as shown in §§ 83 and 84. When the curve has advanced so far as to render a new transit point necessary, this should be established at a full station. The subtangents from the two transit points should then be produced to intersect and should be measured for equality with each other and with their calculated length. The distance from their intersection to the middle of the long chord should also be measured as a check on the deflections. When no perceptible errors remain, the curve may be produced as before until the P.T. is reached. It is evident that correct measure is indispensable to correct alignment on curves. Should obstacles on the surface necessitate triangulation, more than ordinary care must be exercised and as many checks introduced as possible. The triangles should be so arranged that all of the angles and most of the sides may be measured.

Test levels are carried over the surface with great care, each turning point being made a permanent bench, and its elevation determined with a probable error not exceeding 0.005 ft. Levels may be carried down a shaft on a series of bolts or spikes about 12 ft apart in the same vertical line, the distances being measured by the same level rod as that with which the benches are determined. The measures should be taken between two graduations of the rod, not using the end of the rod, which may be slightly worn. Fine horizontal lines on the heads of the bolts may be used to mark the exact distances. After the shaft reaches the level of the tunnel, the depth may be measured more directly with a steel tape, the entire length of which has been corrected at the given temperature, by comparison with the same rod.

If the **grade of a tunnel** is to be continuous, it should be assumed at something less than the maximum of the road, but not less than 0.10 per station, which is required for drainage. If a summit is to be made in the tunnel, the grade

from the upper end should not exceed 0.10 per station. Grades are given in the tunnel from day to day, or as often as required by the progress of the work, the marks being made on the sides at some arbitrary distance above grade. Turning points should be taken on permanent benches.

The least width of a tunnel in the clear should be for single track about 16 ft; for double track this distance should be increased by the distance between tracks. The height in the clear above the tie should be 22.5 ft for both single and double track, allowing for tie and ballast, this distance being measured at the center lines of each track. The form of section depends somewhat on the material traversed. In perfectly solid rock a nearly rectangular section may be used, the roof being slightly rounded. In dry clay and stratified rock a flat arch may be used and in other cases a full-centered arch. The latter form is rather to be preferred on account of the better ventilation afforded. The sides are made vertical, battered, or curved, as necessity or taste may dictate. In wet and infirm soil an invert floor may be required; otherwise, it is made level transversely. When a lining is required, the original section must, of course, be made large enough to allow for the masonry and the temporary timber supports behind it. Hard-burned brick is usually adopted for arching, being durable and easily handled. In loose rock the arching may be 13 to 26 in. thick; in wet and yield soil a thickness of from 26 to 39 in. may be necessary. The walls may be from $2\frac{1}{2}$ to 6 ft thick.

In forming a tunnel, a heading or gallery of smaller cross section is first driven and afterward enlarged to the full size required. In firm clay or loose rock, which will temporarily support itself until the masonry can be put in, it is better to drive the heading along the floor (at subgrade) of the tunnel, the remaining material being then easily thrown down in sections as the arching is advanced. In solid rock or wet earth a top heading (along the roof) is generally preferred. The dimensions of a heading driven by hand are usually 8 ft high by 8 or 10 ft wide, but in solid rock where drilling machinery is introduced it is advantageous to make the heading as wide as the tunnel at once. By drilling holes into the face at points about 5 ft each side of the center and converging on the center line at a depth of about 10 ft, a triangular mass of rock may

be blown out, and the space thus gained facilitates the blasting of the adjacent rock on either side. An advance of about 10 ft in each day of 24 working hours may thus be made, if nitroglycerine in some form is used as the explosive agent. Owing, however, to unavoidable delays from various causes, this rate or progress cannot always be maintained. At the Hoosac tunnel the greatest advance in one week was 50 ft; in one month 184 ft at one heading. At the Musconetcong tunnel a heading 8×22 ft in syenitic gneiss was advanced at the average rate of 137 ft per month for 6 months, the maximum being 144 ft—the enlargement of the tunnel to full size going on at the same time, a few hundred feet behind. At the St. Gothard tunnel the north heading 2.5×3 meters was advanced in mica gneiss, during the year 1875 at the average daily rate of 3.71 meters, with a maximum of about 4 meters, but the enlargement was not made. The south heading advanced at the rate of 2 meters a day, timbering being at times necessary.

In ordinary clay a heading may be driven at 75 to 180 ft per month, according to circumstances, where timbering is put in. The enlargement, including timbering and masonry, may be advanced at 20 to 60 ft per month. Small tunnels for water conduits are driven through dry clay at the rate of 10 ft per day, the masonry following at once without timbering.

The compressed air used to drive the drilling machinery serves to supply ventilation also. When this is wanting or proves insufficient, exhaust fans are used. At Mont Cenis a horizontal *brattice* or partition was built in the tunnel, dividing it so as to secure a circulation of air. When foul gases are encountered, ventilation becomes a serious question, and in one instance an important work was abandoned for this cause.

Cross sections of the heading and also of the tunnel enlargement should be measured at intervals of about 20 ft, as soon as opened, to see that the sides, roof, and floor are taken out to the prescribed lines, at the same time that the latter are exceeded as little as possible. In solid rock, since some material outside the true section will necessarily be thrown down, leaving an irregular outline, it is well to take two cross sections at the same point, one following the projections and the other the recesses of the rock, from which an average section may be estimated. A daily or, at least, a weekly record of operations

should be kept in tabular form and the progress indicated by a profile and cross sections drawn on a sufficiently large scale to show details.

The drainage of a tunnel is best secured by a line of stoneware or cement pipe laid in a trench along each side and covered with ballast or other loose material. The entire floor is thus made available for the use of the trackmen. When an invert is used, the drain is placed in the center between tracks. If the amount of water is large, drain pipe may be laid behind the walls, and the back of the arch may be covered with asphaltum, or coal tar, to prevent a constant dripping on the track.

320. Retracing the line. As the grading progresses, in either excavation or embankment, the principal transit points are established on the roadbed from the points of reference, and the center line is retraced, by stakes set every 50 ft. Transit points on grade should be fixed on stout durable posts firmly set in the ground and standing high enough to be easily reached after the ballast is laid. To recover the old line, any discrepancies in measurement must be left between the transit points where they occur and not carried forward. In retracing a curve, if the transit is placed at the forward point, allowing the chain to advance *toward* it, slight differences in measurement will not affect the position of the curve. If any short or long stations have been introduced on the location, their position on the line must not be changed in retracing. The chain may be adjusted so that its measures will agree with the recorded distances between transit points. Offsets are made right and left from the new stakes to see that the roadbed is of the full width at all points. The levels are also carried over the grade, and any remaining cut or fill found necessary is marked on the back of the stakes, owing to allowance being made for the probable settlement of embankments.

321. As the work approaches completion, the contractor goes over the line, dressing it to grade and opening the side ditches if this has not been previously done.

Drain tile should be laid at the bottom of these ditches and lightly covered with earth, particularly if the cut be wet. These not only prevent the water from reaching the ballast, but also, by keeping the foot of the slope comparatively dry,

prevent the earth from sliding down and filling up the cut. There is also a marked economy in their use, as the cost is trifling, and all further excavation of mud and water from the cut is generally obviated. Should any springs appear in the slope, a branch line of smaller tile may be laid to meet it. If the slope is liable to be overflowed from the surface above, an open ditch should be dug a few feet beyond the slope stakes, leading the surface water to discharge elsewhere.

ESTIMATES

322. The final estimate is a complete statement in detail of the amount of work done and materials provided in the construction of the road and is the basis of final settlement between the company and contractor. Its preparation should be begun as soon as possible after the work is in progress and should be continued, as fast as the necessary data are accumulated, while the circumstances are still fresh in mind, and when any omissions in the field notes may be readily supplied. The content of each prismoid, the classification of its material, and the length of haul to which it is subject should be matters of special record in a book provided for that purpose. These results, having been carefully computed by exact methods, form a standard of comparison for those approximate results which must be had from time to time during the progress of the work and furnish a limit to the amounts of the monthly estimates. The same remark applies to all other items of labor and material. The notes and record of the final estimate should be particularly full and exact in respect to all such items as will be inaccessible to measurement at the completion of the work, such as foundation pits, foundation courses of masonry, culverts, and works under water.

323. Monthly estimates. On or before the last day of every month during the progress of construction, measurements are taken to determine the total amount of work done and material provided up to that date. The estimates based on these measurements are called monthly estimates. It is frequently necessary to take measurement for both monthly and final estimates at other times than the end of the month, as in the case of foundations which are not long accessible. With respect to each piece of work satisfactorily completed,

the monthly estimate should be exact, and identical in amount with the final estimate. With respect, however, to items of work in progress at the time of measurement, the monthly estimate is only approximate and yet should be as precise as the nature of the case will allow; and the quantities stated should not be in excess of fair proportion of the total quantities given on the final estimate for the same piece of work.

A **special field book** is devoted to monthly estimate notes. Each page should be dated with the day on which the notes on it were taken. The notes consist of measurements of all sorts, principally of cross sections partially excavated. These sections should be at the same points on the line as the original sections, so that comparisons may be made. Wherever the excavation is finished to grade, it is only necessary to write "completed" opposite such stations, and the quantities may be taken from the final estimate or computed from the original notes. It is frequently necessary to retrace portions of the center line in taking estimate notes, so that all the field instruments are required, but a party of three or four men is usually sufficient.

If the contractor has provided materials, such as stone and lumber, which are not as yet put into any structure when the estimate is taken, these should be measured and entered under the head of **temporary allowance**, an arbitrary price being used somewhat below the actual value of the material as delivered. Such allowances should never be copied from one month's estimate to the next, but made anew on such material as may be found that seems to require it. But all *completed* items of contract work, and of extra work when ordered by the engineer, are necessarily copied from one monthly estimate to the next during the continuance of the contract.

A **blank form** is used by the resident engineer in reporting monthly estimates, on which a column is provided for each class of material and work required by the contract, while the several lines, headed by the numbers of the proper stations, are devoted to the different cuttings, structures, and so on, in consecutive order as they occur on the line of road. The estimates are made out and reported separately for the several sections into which the line of road is divided for letting.

These reports are reviewed by the division engineer, and the footings are copied on another blank, which is the monthly estimate proper; the prices are attached to the items, and the amounts extended and summed up. This sum indicates approximately the total amount earned by the contractor up to date, from which is deducted a certain percentage (usually 15%), which is retained by the company until the completion of the contract. From the remainder is deducted the amount of previous payments, which leaves the amount due the contractor on the present estimate. A blank form of receipt is appended, to be signed by the contractor.

327. *To find the middle ordinate m , for 1 station, or 100 ft, on any curve, in terms of the degree of curve D .*

Referring to Fig. 174 we have in the right triangle AGH ,

$$GH = GA \cdot \tan GAH$$

But $GA = \frac{1}{2}AB = \frac{1}{2}C$, and (Table XLI, 18) $GAH = \frac{1}{4}AOB = \frac{1}{4}\Delta$; hence,

$$M = \frac{1}{2}C \cdot \tan \frac{1}{4}\Delta \quad (308)$$

a general expression for the middle ordinate of any chord.

If in this equation we make $C = 100$, Δ becomes D ; and, denoting the corresponding value of M by m , we have

$$m = \frac{1}{2}100 \tan \frac{1}{4}D \quad (309)$$

whence the **rule**, *Multiply the natural tangent of $\frac{1}{4}$ the degree of curve by 100 and divide by 2.* Thus, the values of m in the 5th column of Table I have been calculated.

328. *To find the middle ordinate for any chord in terms of the chord and radius.*

Referring to Fig. 174, we have

$$GH = OH - OG = OH - \sqrt{AO^2 - GA^2}$$

or

$$M = R - \sqrt{R^2 - \left(\frac{c}{2}\right)^2} \quad (310)$$

When $C = 100$, we have, for the middle ordinate of one station,

$$n = R - \sqrt{R^2 - 2500} \quad (311)$$

For any subchord c , less than 100, we have, for the middle ordinate,

$$\left. \begin{aligned} m_1 &= R - \sqrt{R^2 - \left(\frac{c}{2}\right)^2} \\ m_1 &= R - \sqrt{\left(R + \frac{c}{2}\right)\left(R - \frac{c}{2}\right)} \end{aligned} \right\} \quad (312)$$

or

If $c^4/64R^2$ is added to the quantity under the radical in equation 312, it becomes a perfect square, giving

$$m_1 = \frac{c^2}{8R} \quad \text{nearly} \quad (313)$$

which is a very useful formula, although approximate. The error in m_1 does not exceed 0.002 for any subchord c when the radius is greater than 800. On a 20° curve the error will be 0.002 for a chord of 50 ft; and on a 40° curve the error in m_1 will be only 0.003 for a chord of 33 ft. Equation 313 is therefore practically correct in all cases for *finding the middle ordinates of rails*. Table VIII is calculated by equation 312.

From the last equation it appears that, with a given radius, the middle ordinate varies nearly as the square of the chord. We may, therefore, find the middle ordinate of a rail whose length is c by the proportion,

$$(100)^2 : c^2 :: m : m_1$$

or

$$m_1 = \frac{c^2 m}{10,000} \quad \text{nearly} \quad (314)$$

in which m is obtained from Table I, column 5, for the given radius or degree of curve.

Example. What is the middle ordinate of a 33-ft rail when curved for a 20° curve?

Equation 314:

$$m_1 = \frac{1089 \times 4.374}{10,000} = 0.476 = 5\frac{1}{16} \text{ in.}$$

When a long rail is bent for a sharp curve, observe that c is the length of the chord of the rail—not of the rail itself.

For the chord of half a rail the middle ordinate is one-fourth the middle ordinate of the whole rail. Thus, in the previous example it would be 0.119 or $1\frac{7}{16}$ in.

Instead of using the chord of the whole rail, it may be more convenient to assume a chord shorter than the rail, especially when the chord is not an exact number of feet, knotting the string to the length assumed, and applying it to different portions of the rail successively.

329. Testing track curvature. The proper curvature of a rail is tested by measuring its middle ordinate from a small cord stretched from end to end and touching the side of the rail head. The cord should also be stretched from the middle point of the rail to either end, and the middle ordinate of each half-length measured, to test the *uniformity* of curvature.

(a) A common rule for finding the degree of curve of a track is "*The middle ordinate in inches of a 62-ft chord equals the degree of curve.*"

In equation 313 substitute 1 in. for m_1 and 5730 for the radius of a 1° curve, and we have

$$\frac{1}{12} = \frac{c^2}{8(5730)}$$

or

$$c^2 = 3820, \quad c = 61.6 \text{ or } 62 \text{ ft approx.}$$

Finally, if it is assumed that the radius varies inversely as the degree of curve, the rule obtains as stated.

(b) *Another method* is illustrated by Fig. 175.

Select a point A at a rail joint; sight along a line tangent to the inner rail at a point as D , and note its intersection with the other rail at C . Count the number of rail lengths whole and fractional in ABC .

Let n denote the number of rail lengths in ABC .

Combining equation 313 and $R = 5730/D$, and solving for D , we get

$$D = \frac{8 \times 5730 m_1}{c^2}$$

Considering the lengths of the chord AC and the arc ABC equal, we have, for 30-ft rails, $c = 30n$, and, for 33-ft rails, $c = 33n$.

This equation for the standard gauge of 4 ft 8½ in. = 4.708 ft becomes, for 30-ft rails,

$$D = \frac{240}{n^2} \quad (\text{approx.}) \quad (315)$$

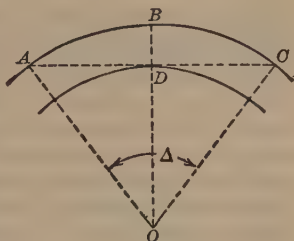


FIG. 175.

and, for 33-ft rails,

$$D = \frac{198}{n^2} \quad (\text{approx.}) \quad (316)$$

Equations 315 and 316 give the degree of the outer rail and that only roughly, depending on the *actual gauge*, which is sometimes increased on curves.

330. Grade stakes are placed at one side of the track. The tops of the stakes are set for the grade of the *top of the rail*, which is at a certain definite height above the "sub-grade" of the profile and cross sections.

Track on tangents is level transversely. If the grade is uniform, the elevations of stations differ by a constant amount. On curves, the top of the stake indicates the elevation for the outer rail, the inner rail carrying the regular grade.

The track is gradually raised by track jacks and by tamping until it is at the proper elevation, as proved by a track level extending from the top of a stake to the top of the rail.

331. Raising track. With use, track tends to work down below grade. It is raised by jacking and tamping ballast under the ties, concentrating the tamping near the rails so that track will be stable laterally. Grade stakes for raising track are established as follows:

Before the work is begun, an accurate profile is taken of the top of both rails at 50-ft intervals. These profiles are plotted to a vertical scale large enough to show hundredths of a foot. The desired profile is determined graphically. It is composed of straight lines and curves drawn with curve templates representing the top of the "*profile rail*." On curves this is the inside rail, and on tangents it can be either rail, but a certain rail is usually designated as the profile rail for the entire railroad.

The profile must be arranged so that it will produce smooth riding qualities, require a minimum of raising track, and not require either rail to be lowered at any point. The raise at each point is scaled from the final profile.

The grade stakes are set about 1 in. inside the profile rail. They are driven so that the top of the stake is above the base of rail by the amount of the raise required. This is measured

with a short scale from the side of a pencil pressed upward against the base of the rail and extending to the stake.

The profile rail is raised according to the stakes, and the opposite rail is set from it, using a track level. The required superelevation on curves can also be set with the track level.

This method has two advantages. An instrument is required only for the original profile, and the grade stakes are nearly flush and therefore out of the way.

332. Rate of grade. The rate of grade or merely the grade is the change in elevation in a given horizontal distance. It is usually expressed in terms of a per cent or a ratio, due account being taken of sign. For example, if in a horizontal distance of 50 ft there occurred a fall of 2 ft, the rate of grade (or grade) would be -4% or -0.04 .

333. Grade line. A grade line is the profile of future construction.

VERTICAL CURVES

334. An abrupt change in rate of grade which would be indicated by an angle in the grade line cannot be tolerated in a railroad track or in a highway pavement. Accordingly, straight grade lines are always connected by curves in the profile called vertical curves.

335. Change in rate of grade. A change in grade is defined as the preceding grade subtracted from the following grade with due attention to signs.

A summit may be defined as a change from a positive to a negative grade and a sag as the reverse. Changes in grade requiring a vertical curve may also occur between two grade lines having different grades of the same sign.

336. The shape of a vertical curve. To produce the best riding qualities, a vertical curve should be such that the change in grade is uniform throughout. Such a curve is a parabola having a vertical axis. As elevations on such curves are easy to compute, they are used exclusively for vertical curves except when a graphic solution will suffice.

337. The properties of a parabola. The general equation for a parabola whose axis is parallel to the Y axis is the following:

$$y = ax^2 + bx + c \quad (317)$$

338. The slope. The slope of this curve at any point is given by the derivative,

$$\frac{dy}{dx} = 2ax + b \quad (318)$$

339. The rate of change of slope. The rate of change of slope is given by the second derivative,

$$\frac{d^2y}{dx^2} = 2a \quad (319)$$

In a vertical curve, the rate of change of slope is the rate at which the grade changes. It is called the **rate of change of grade**. Since $2a$ is a **constant**, the grade changes **uniformly throughout the curve**, which is the desired condition. By specifying the value of $2a$, the desired vertical curve is obtained in the same manner as, by specifying the value D , the desired horizontal curve is obtained.

340. *The difference in elevation between a vertical curve and a tangent to it is equal to the value a multiplied by the square*

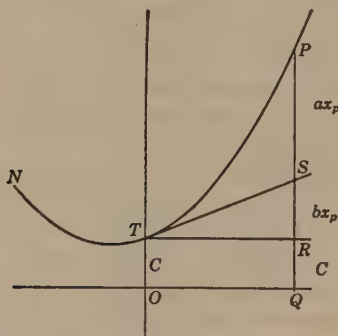


FIG. 176.

of the horizontal distance from the point of tangency. This may be proved as follows.

(Fig. 176) Let NPT be any vertical curve having a tangent TS at any point T . Construct a rectangular coordinate frame so that the Y axis is vertical and passes through T , and the X axis is at a distance C from T as shown. The equa-

tion for the parabola will then be equation 317, in which the values of y are differences in elevation and the values of x are differences in plus.

Construct TR parallel to the X axis.

At any point P on the parabola where $x = x_p$ and $y = y_p$,

$$y_p = QR + RS + SP$$

But

$$QR = C$$

RS = slope of parabola at the Y axis
(where $x = 0$) multiplied by x_p

$$= (2ax + b)x_p = (0 + b)x_p$$

from equation 318

$$= bx_p$$

Substituting gives

$$y_p = SP + bx_p + C$$

but

$$y_p = ax_p^2 + bx_p + C \quad \text{from equation 317}$$

Equating gives

$$SP = ax_p^2 \tag{320}$$

Q.E.D.

Corollary 1. The horizontal lengths of any two tangents from a point to a vertical curve are equal.

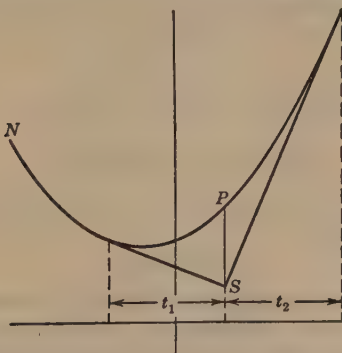


FIG. 177.

(Fig. 177) Let t_1 and t_2 be the horizontal lengths of two tangents from the point S to a vertical curve.

Construct SP vertically from S to the curve.

Then,

$$SP = at_1^2 = at_2^2$$

Hence,

$$t_1 = t_2$$

Q.E.D.

Corollary 2. A chord to a vertical curve has a rate of grade equal to that of the curve at a point *halfway* (measured horizontally) between the *points of intercept*.

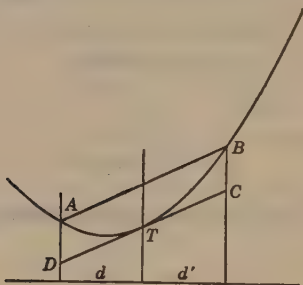


FIG. 178.

(Fig. 178) Let AB be any chord of a vertical curve having a horizontal length $2d$.

Construct the tangent DTC so that the point of tangency T is halfway (measured horizontally) from A to B .

$$d' = d \text{ by construction}$$

$$AD = BC \text{ from equation 320}$$

$$AD \parallel BC \text{ by construction}$$

Hence, $ADBC$ is a parallelogram having opposite sides equal and parallel, and

$$AB \parallel DC$$

Q.E.D.

341. The procedure for computing a vertical curve.

The steps used in computing the elevations for a vertical curve follow in order. The actual vertical curve computed is shown in Fig. 180. The results of each computation are

given with each step. The units used throughout are: for elevation differences, feet; for horizontal distances, stations (that is, units of 100 ft); for rates of grade, per cent.

1. Choose a value for $2a$. $2a$ is here expressed as the rate of change of per cent of grade per station. For example, if a vertical curve of 4 stations ran from a plus grade of 3% to a minus grade of 5%, the value of $2a$ would be -2% per station, that is, a total change of -8% in 4 stations. Thus:

$$2a = \frac{-5\% - 3\%}{4 \text{ sta.}} = -2\% \text{ per station}$$

In railroad practice, the velocity of the traffic governs the value used for $2a$. Usually in sags $2a$ is held at $+0.1\%$ per

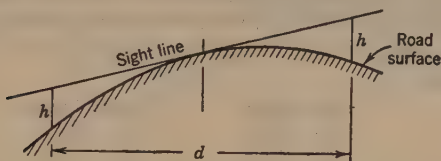


FIG. 179.

station and on summits -0.2% per station. See also § 346.

In highway practice the sight distance is important, and the value of $2a$ is often computed from it. For example, if it were desired that two points d stations apart and each h ft above the pavement, should be intervisible, the value of $2a$ would be derived as follows (Fig. 179):

$$h = -a\left(\frac{d}{2}\right)^2 \quad \text{from equation (320)}$$

or

$$2a = -\frac{8h}{d^2} \quad (321)$$

Assume

$$h = 3' 9'' \text{ or } 3.75 \text{ ft}$$

$$d = 7 \text{ sta. (700 ft)}$$

$$2a = -0.612\% \text{ per station. Choose } -0.6\% \text{ per station}$$

2. Determine the rates of grade of the two grade lines (tangents) and the plus and elevation of their intersection V .

The final grade lines for a location are usually worked out on profile paper. The rate of grade for each straight section is determined by taking off elevations at two widely separated stations and dividing their difference in elevation by their difference in the plus. In railroad practice, the grades are so light that a slight change in the plus of the intersection V of two grades has very little effect. Accordingly, the intersections are usually placed at stations, and their elevations are used in computing the grades. In highway practice the steeper grades usually prevent this procedure, and the positions and elevations of the grade intersections must be computed.

Example. Required to compute the elevations for every station and half station of a vertical curve to connect the two tangents, defined below, and having a value of $2a = -0.6\%$ per station.

Back Tangent		Forward Tangent	
Sta.	Elev.	Sta.	Elev.
30	38.5	45	58.4
40	59.6	55	45.5
Diff. = 10	21.1	10	-12.9
Grade = +2.11%		-1.29%	

To find the plus and elevation of V (Fig. 180).

Let x = the number of stations that V is beyond station 40. Equating the two expressions for the elevation of V , we have

$$59.6 + 2.11x = 58.4 + 1.29(5 - x)$$

$$x = 1.5441$$

$$\text{Plus } V = 41 + 54.41$$

$$\text{Elev. } V = 62.86$$

3. Compute the length of curve expressed in stations, L . L is equal to the total change in grade $g_2 - g_1$ divided by the rate of change of grade per station, $2a$.

$$L = \frac{g_2 - g_1}{2a} \quad (322)$$

Substituting gives

$$L = \frac{-1.29 - 2.11}{-0.6} = 5.6667 \text{ sta.}$$

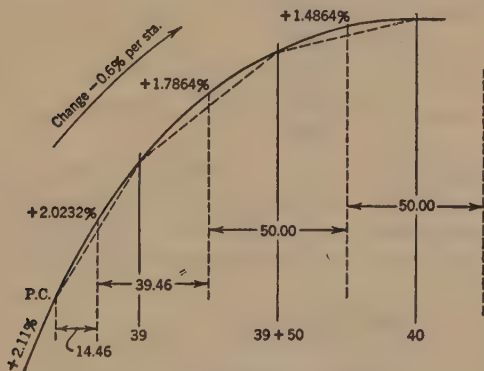
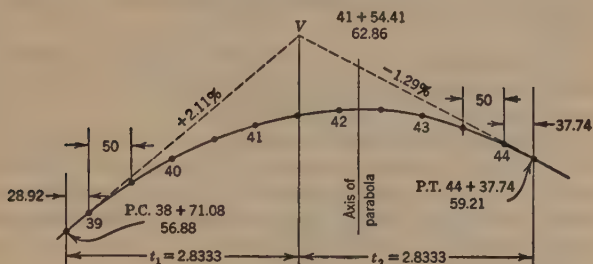


FIG. 180.

4. Compute the plus of the P.C. and the P.T. From corollary 1:

$$\text{Plus P.C.} = \text{plus } V - \frac{1}{2}L = 38 + 71.08$$

$$\text{Plus P.T.} = \text{plus } V + \frac{1}{2}L = 44 + 37.74$$

These values give the lengths of the subchords at the P.C. and the P.T.

5. Compute the elevations of the P.C. and the P.T.

$$\text{Elev. P.C.} = \text{elev. } V - \frac{1}{2}Lg_1 = 62.86 - 2.8333(2.11) = 56.88$$

$$\text{Elev. P.T.} = \text{elev. } V + \frac{1}{2}Lg_2 = 62.86 + 2.8333(-1.29) = 59.21$$

6. Compute the elevatings of the curve. There are two chief methods of computing vertical curves. Either can be used for any vertical curve desired. Both methods are described here. Examples of each are worked out for the same curve.

342. Method 1. Construct chords connecting the adjacent points on the curve where elevations are desired including the P.C. and the P.T. See Fig. 180.

(a) **Compute the changes in rates of grade.** Compute the change in rate of grade δ_1 between the tangent and the first chord. Since the chord is parallel to the curve at its mid-point (corollary 2), this change is equal to the change in rate of grade of the curve from the P.C. to a point above the mid-point of the chord, or

$$\delta_1 = \frac{\frac{1}{2}C}{100}2a$$

$$\delta_1 = \frac{\frac{1}{2}28.92}{100}(-0.6) = -0.0868$$

Compute δ_2 , the change in rate of grade between the first and second chords. This is equal to the change in rate of grade of the curve from the point above the mid-point of the first chord to the point above the mid-point of the second chord.

$$\delta_2 = \frac{\frac{1}{2}C_1 + \frac{1}{2}C_2}{100}2a$$

$$\delta_2 = \frac{\frac{1}{2}28.92 + \frac{1}{2}50}{100}(-0.6) = -0.2368$$

Compute: δ_3, δ_4 , etc. $= (50/100) (-0.6) = -0.3$.

Compute the changes in rate of grade at the P.T. and the point just previous to the P.T. in a manner similar to that at the P.C. and the point immediately following the P.C. See Fig. 181.

Check. The sum of the changes thus computed should be equal to the total change in grade between the tangents (-3.40%) .

(b) **Compute the grades of the chords.** Beginning with the rate of grade of the first tangent, add each δ successively, thus

are obtained. It may be noted that the differences in elevation change by uniform increments where the chords are uniform in length. The increments are equal to the change in rate of grade per station multiplied by the square of the length of the chord in stations.

$$\text{Increments in diff. in elev.} = \left(\frac{C}{100} \right)^2 (2a)$$

$$= \left(\frac{50}{100} \right)^2 (-0.6) = -0.15$$

In the example, the differences in elevation change by the increment -0.15 from station 39 to station 44. It is therefore unnecessary to compute the part of the table outlined by the rectangle.

The final elevations are usually reduced to the nearest hundredth of a foot.

343. Method 2 (Fig. 182). Method 2 for computing the elevations is based on equation 320.

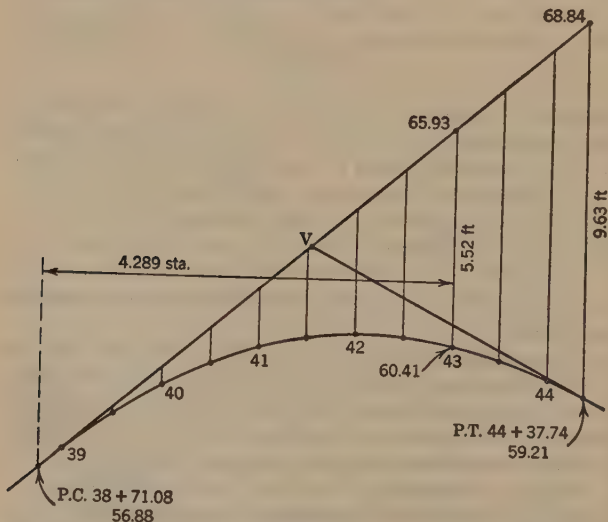


Fig. 182.

(a) Compute the horizontal distances from the P.C. of all the points on the curve whose elevations are desired. These are known as values of x . See Fig. 183.

(b) Compute the x^2 values.

(c) Multiply the x^2 values by a . These will be the vertical distances from the tangent to the curve at the points required.

(d) Compute the tangent elevations for the same plusses. The first tangent is produced to a point above the P.T.

(e) Compute the elevations of the curve. The values of ax^2 are the differences in elevation between the vertical curve and the first tangent (equation 320). The curve elevations are obtained by subtracting these values from the elevations of the corresponding points on the tangent. The elevation of the P.T. computed by this means should agree with the elevation of the P.T. previously established.

Notes on computation. If it is desired to reduce the size of the values of x^2 , the ax^2 values can be computed partly from one tangent and partly from the other. When the second tangent is used, the values of x are measured from the P.T.

Station	x	x^2	ax^2	Tangent Elev.	Elev. Used
P.C. 38+71.08	0.0	0.0	0.0	56.88	56.88
39	0.289	0.08	0.02	57.49	57.47
39+50	0.789	0.62	0.19	58.54	58.35
40	1.289	1.66	0.50	59.60	59.10
40+50	1.789	3.20	0.96	60.66	59.70
41	2.289	5.24	1.57	61.71	60.14
41+50	2.789	7.78	2.33	62.76	60.43
42	3.289	10.82	3.25	63.82	60.57
42+50	3.789	14.36	4.31	64.87	60.56
43	4.289	18.40	5.52	65.92	60.41
43+50	4.789	22.93	6.88	66.98	60.10
44	5.289	27.97	8.39	68.04	59.65
P.T. 44+37.74	5.667	32.11	9.63	68.84	59.21

FIG. 183.

This method provides no checks. It can be checked by computing separately from both tangents.

344. Simplified method. It will be found that, if the P.C., the V , and the P.T. come exactly at stations, the work is considerably simplified. This can be effected by adjusting the grades to bring V at a station and then adjusting the length of the curve to an even number of stations, as follows:

Solve (equation 322):

$$L = \frac{g_2 - g_1}{2a}$$

Then, taking the nearest even value of L and solving give

$$2a = \frac{g_2 - g_1}{L}$$

The value of $2a$ thus obtained is then used throughout the usual computation.

345. Short vertical curves. Short vertical curves and highway crowns can be computed by adroit use of equation 320 and the values shown in Fig. 184, which may be easily proved.

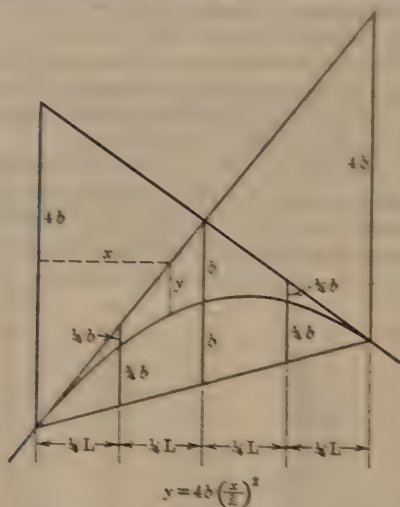


FIG. 184.

346. As to desirable values for the linear deflection $2a$, the American Railway Engineering Association has recommended the limits of 0.10 on summits, and 0.05 in sags for first-class roads with heavy traffic, whereas for minor roads with light traffic these limits may safely be doubled. It would be well to change the limit of 0.05 to 0.06 in order to avoid the third decimal place in figuring grades.

SUPERELEVATION AND EXPANSION

347. Elevation of the outer rail on curves. When a car passes around a curve, a centrifugal force is developed

which presses the flanges of the wheels against the outer rail. This force acts horizontally and varies as the square of the velocity and inversely as the radius of the curve. Denoting the centrifugal force by F , we have from the theory of mechanics, $F = Wv^2/32.166R$, in which W = weight of loaded car in pounds, v = velocity in feet per second, and R = radius of curve in feet.

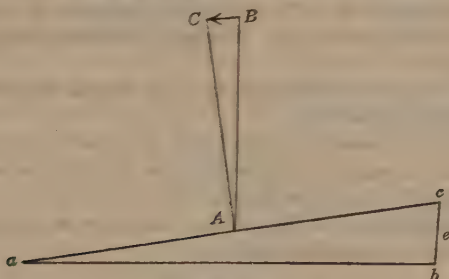


FIG. 185.

In Fig. 185 denote BA by W , BC the horizontal component of W by F' , and bc by e = elevation of the outer rail. From similar triangles abc and ABC ,

$$CB = F' = \frac{We}{ab}$$

Equating F' and F , and solving for e , we get

$$e = \frac{ab \cdot v^2}{32.166R} \quad (323)$$

The distance ab is the horizontal distance corresponding to the inclined distance between bearing points of the wheels on the rails. This is approximately equal to 4.9 ft.

The velocity of the train, V , is usually given in miles per hour whereas that in equation 323 is in feet per second, v . Now $3600v/5280 = V$ and $v = 5280V/3600$. Inserting this value of v in the equation together with the value of $ab = 4.9$ and collecting terms, we get

$$e = 0.3278 \frac{V^2}{R} \quad (\text{in feet}) \quad (324)$$

$$= 0.000686 V^2 D \quad (\text{in inches}) \quad (324A)$$

Ordinarily, the inner rail of the curve is kept at the grade, the outer rail being elevated the full amount e . On some roads, however, the center line defines the grade and then the outer rail is raised $\frac{1}{2}e$, and the inner depressed $\frac{1}{2}e$.

The first part of Table IX is given in thousandths of a foot and is based on equation 324 where $ab = 4.9$ ft. The second part of this table is given in fractional parts of an inch taking $ab =$ the gauge $= 4' 8\frac{1}{2}'' = 4.708$ ft. This part of the table is from the Manual of the American Railway Engineering Association.

348. The proper elevation may be found mechanically by the following method:

To find on a curved track the length of a chord whose middle ordinate shall equal the proper elevation of the outer rail for any velocity V in miles per hour.

By the conditions of the problem, we have m_1 in equation 313 equal to e in equation 323, or

$$\frac{c^2}{8R} = \frac{gV^2 0.06688}{R}$$

$\therefore$

$$c = 0.73144V\sqrt{g} \quad (325)$$

When $g = 4.708$,

$$c = 1.587V \quad (326)$$

Lay off the chord c on the rail of the track, stretch a piece of twine between the points so found, and measure the middle ordinate; it will equal the proper elevation.

349. The *velocity assumed* in the preceding formulas should be that of the fastest regular trains which will pass over the curve in question, since the flanges would be forced against the outer rail were there no centrifugal force developed, by reason of the wheels being rigidly attached to the axles, and the axles being parallel.

The rails on tangents should be level transversely except on very flat curves where spirals are not employed. In such cases one rail of the tangent is gradually elevated, beginning a short distance from the P.C. and the P.T. At a P.C.C. the elevation should be an *average* of the elevations due to the two arcs. Owing to the difficulty of properly adjusting the elevation of rail, it is objectionable to have arcs of very dissimilar radii join each other; and the objection is much

greater in the case of reversed curves unless separated by a short tangent. See § 70.

On the other hand, a short tangent between arcs which curve in the same direction should be avoided, since it makes a "flat place" both in line and levels, at once unsightly and injurious to the rolling stock.

In the case of turnouts, however, no elevation of rail is possible (except when both tracks curve in the same direction).

350. Owing to the *expansion of the rails* by heat, a space must be left at the rail joints. The highest temperature of a rail in the summer sun is about 130° F.

If the temperature of the rails when laid is this amount, they should be laid close together, but if at a lower temperature an allowance should be made.

The coefficient of expansion for iron or steel is about 0.0000065. When 33-ft rails are laid at a temperature of 90° F the expansion spacing should be 33 (130-90) 0.0000065 or 0.0064 ft, and similarly at other temperatures.

Many railroads furnish their track-laying crews with a table giving the correct amount of expansion spacing needed at different temperatures, and properly marked metal shims are provided for field use.

Wherever **sidings** are required, the necessary frogs and long switch ties should be provided in advance, so that they may be put in place at the time of laying the main track. For every road crossing at grade, heavy oak plank should be provided and laid on the ties as soon as the rails are spiked, so that the highway travel may not be impeded.

CHAPTER XVII

STRING LINING CURVES

351. Under the impact of traffic, track alignment is subject to continual change. Curves develop flat or sharp spots and poor spirals, which produce lateral shock and sway in the trains moving over them to an extent unpleasant to passengers, injurious to track and roadbed, and sometimes dangerous. To reduce the recurring costs of maintaining smooth curve alignment it is important that a method be employed which requires the minimum moving or "throwing" of track. *The methods employed for giving original alignment when applied to track already in place are cumbersome, usually require several laborious trials, and cause excessive track throwing.*

The method known as **string lining curves**, here described, fulfills the foregoing requirement with very little field work or computation and is so inexpensive, accurate, and flexible that it should always be employed for the realignment of curves.

352. The procedure involved requires four steps, briefly (Fig. 186):

1. *Marking the outer rail at regular intervals throughout the curve.*

2. *With a string and scale determining the middle ordinates at these points.*

3. *From the middle ordinates measured, computing the distances which the track must be moved or "thrown."*

4. *Setting stakes with tacks to show the new position of the track and throwing the track accordingly.*

After the track has been thrown, the middle ordinates of the new position should be measured as a check on the computation and the accuracy with which the track has been thrown.

353. Two principles are involved:

1. *On a curve of constant curvature middle ordinates at all*

points are equal when measured from chords of equal length (apparent from equation 310).

2. Middle ordinates when measured from chords of equal length are proportional to the degree of curvature (very nearly).

In equation 313, substituting for R its value given in equation 5, we have

$$m_1 = \frac{c^2}{45,840} D \quad \text{nearly} \quad (327)$$

With c constant, m_1 varies directly as D .

It is evident that, exclusive of spirals, the middle ordinates should be equal throughout a curve or each arc of a compound curve. Where spirals occur or are to be introduced, the middle ordinates should vary as it is desired to make D vary. Since it is a basic principle of all types of spirals that D shall change uniformly at a rate proportional to the distance, the ordinates should change by uniform increments, that is, form an arithmetic progression.

MARKING THE RAIL

354. Position of Marks (Figs. 186 and 187). Keel marks are placed on the unworn portion of the inside of the head of the outer rail and numbered on the web at intervals (measured

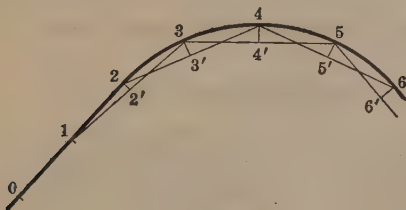


FIG. 186.

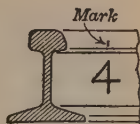


FIG. 187.

with a metallic tape) equal to one-half the chord length, throughout the curve and far enough on adjacent tangents to obtain middle ordinates of zero for six or seven stations.

355. Intervals. On main-line track a 30-ft to 40-ft interval gives excellent alignment control without unduly elaborating the work. Using rail joints for stations eliminates taping but gives inaccurate middle ordinates. It is convenient for

subsequent determination of superelevation to employ an interval which, with the unit used for middle ordinates, gives approximate D without computation.

The following intervals, computed from equation 327, are suggested:

Interval ($\frac{1}{2}$ chord) ft	Unit Used for Middle Ordinate	$D = \frac{\text{measured middle ordinate}}{\text{unit listed below}}$
31	$\frac{1}{8}$ in.	Inches
31	$\frac{1}{4}$ in.	Inches
34	0.01 ft	Tenths of feet
31	0.1 in.	Inches
25	$\frac{1}{8}$ in.	$\frac{5}{8}$ in.
15.5	$\frac{1}{4}$ in.	$\frac{1}{4}$ in.
11	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.

The three last intervals listed are recommended only for sharp curvature.

For siding and yard alignment where the minimum allowable radius occurs, the interval should be one-half the wheel base of the locomotive used. Sharp spots which might cause derailment will thus be discovered.

While the rail is being marked, *positions should be recorded of objects which might limit throws*. Chief among these are: adjoining track, signals, fences, and retaining walls, where clearances must be maintained; and bridges, turnouts, interlocking, and platforms, where the movement of the ties is limited.

At highway crossings often no throw at all can be used.

MEASURING MIDDLE ORDINATES

356. See Fig. 186 and Table A. A strong light string, fishing line, or wire, held taut, is pressed firmly against the marks at stations 0 and 2, and the middle ordinate (hereafter called ordinate) is measured at station 1. The string is then held at stations 1 and 3 and the ordinate measured at station 2, and so on. A wooden rule or a 1-ft section cut from a steel tape can be used. Often at the ends of the spirals a minus ordinate is found where the curve reverses slightly as it runs into the tangent. To measure these, the ends of the string should be held 1 in. or 0.1 ft off the inside of rail head by wooden or aluminum gauges, and this unit should be subtracted from the ordinate measured. To simplify computa-

tion, hundredths of feet or tenths of inches should be recorded as whole numbers, the decimal point being eliminated. Eighths or sixteenths of inches should be recorded as read and later reduced to whole numbers; for example $3\frac{1}{2}$ in. is reduced to 28 eighths or 56 sixteenths.

COMPUTING THROWS

357. The distance which the track is moved *outward* at any point is generally known, and hereafter designated as a

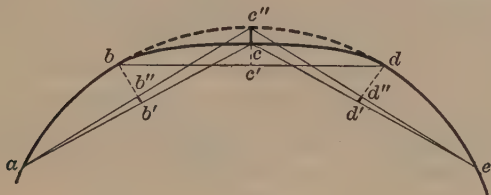


FIG. 188.

plus throw; a throw in the opposite direction or "*in*," a *minus throw*.

In Fig. 188, let a, b, c, d, e be the marks on track and $bb', cc',$ and dd' be the respective measured ordinates.

Then if a *plus throw* is made at c , equal to cc'' , and the ordinates remeasured, the ordinate at c will have been *increased* by cc'' , and the ordinates at b and d will have been *decreased* by $b'b''$ and by $d'd''$, respectively.

But on an actual railroad curve $b'b'', cc'',$ and $d'd''$ will be so nearly parallel that $b'b'' = d'd'' = \frac{1}{2}cc''$.

The rule may be stated:

Rule I. A throw at any station will produce a change in the ordinate at that station equal to and of the same sign as the throw, and will also produce at the two adjacent stations a change in the ordinates equal to one-half the throw and of opposite sign to the throw.

Corollaries

Rule II. The sum of the resulting ordinates must be equal to the sum of the original ordinates.

Rule III. The throw at the first and last station of a curve, as finally computed, must equal zero.

(Since a throw affects the ordinate at adjacent stations, the tangent would be interfered with if the throw at the first and last stations of the computed curve is not zero.)

Note: *Minus throws* may be applied to the tangents beyond the original curve, thus *lengthening the spirals*, but these throws must be chosen so that *no minus ordinate* (showing reversed curvature) will be created in the *final curve*.

Several methods of computing throws have been devised. Two methods are here described. The first method is rapid, accurate, and dependable and should be used except where special requirements necessitate the second method.

FIRST METHOD OF COMPUTATION

358. Example 1, Table A. Listed in the second column are the *measured ordinates* representing a curve obviously in need of alignment.

(a) (Note letter in table.) At station 9 the spiral is *too flat* and at station 8 *too sharp*. Try a throw of -6 at station 8. From *rule I* the resulting ordinates at stations 7, 8, and 9 will be 16, 8, and 5.

TAB

Stations	Measured Ordinates	Resulting Ordinates		
1	0			
2	2	1		
3	3	b 5		
4	12	11		9
5	10		d 14	13
6	12		13	e 13
7	13	16	c 14	13
8	14	a 8	9	
9	2	5		
10	1			
11	0			
	69	← Check →		

(b) At station 3 the spiral is too flat and at station 4 too sharp; try a throw of +2 at station 3.

(c) At station 7 the ordinate of 16 is too large.

(d) At station 4 the ordinate is too large for spiral, and at station 5 too small.

(e) Self-evident.

The final ordinates are listed for study in the fourth column. The trial throws are added algebraically (when more than one throw is made at a given station) and collected in the last column.

When the final ordinates are examined, it is evident that they represent a perfect curve. The ordinates on the curve proper are all equal (13), and the ordinates in the spirals vary in arithmetic progression. The ordinates at stations 2 and 10 are measured from chords extending to points on the tangents and are, therefore, less than required by arithmetic progression.

Assuming that the station interval chosen was 34 ft, and the ordinates were measured in hundredths of a foot, we have

$$D = \frac{0.13}{0.1} = 1.3^\circ \text{ or } 1^\circ 18'$$

LE A

Final Ordinates	Trial Throws		Final Throws
0			
1			
5	b	+2	+2
9			
13		d	+4
13		e	+2
13		c	-2
9	a	-6	-6
5			
1			
0			
69			

The spiral extends from about station 1.5 to station 5, or 119 ft, which, with reference to Table XXXIII, will permit a speed of 60 mph.

359. Example 2. The process illustrated in *Example 1* is elaborated in *Example 2*, and a further corollary to *rule I* is employed.

Corollary to Rule I.

Rule IV. A series of equal throws applied at a series of adjacent stations will produce a change in the ordinates at the first and last station in the series equal to one-half the value of one of the throws and of the same sign as the throws and, at the station immediately preceding and that immediately following the series, a change in the ordinates equal to one-half one of the throws but of opposite sign to the throws.

TABLE B

Sta.	Resulting Changes	Final Changes	Throws
1	$-a$	$-a$	
2	$+2a-a$	$+a$	$+2a$
3	$-a+2a-a$	0	$+2a$
4	$-a+2a-a$	0	$+2a$
5	$-a+2a-a$	0	$+2a$
6	$-a+2a$	$+a$	$+2a$
7	$-a$	$-a$	

Table B. Let a series of five throws of $+2a$ be applied. Computation of the *resulting changes* is shown above. The *final changes* illustrate *rule IV*. It is evident that *rule IV* may be applied to a series of any number of stations.

Table C. The trial throws are lettered in the order in which they were made and a corresponding letter placed at the ordinates resulting from each particular throw or series of throws. The computations can thus be followed. The reason for the application of each throw is reasonably obvious. It is evident that there is no limit to the number of solutions possible. The finish to which the solution is extended depends on the degree of perfection desired in the curve.

Stations	Measured Ordinates	Resulting Ordinates			Final Ordinates	Trial Throws			Final Throws
1	0				0				0
2	4				4				0
3	12				10				0
4	12	$\begin{bmatrix} 10 \\ 16 \end{bmatrix}$	j		16	$\begin{bmatrix} +4 \end{bmatrix}$			+ 4
5	24	$\begin{bmatrix} 22 \end{bmatrix}$			22				0
6	21			$\begin{bmatrix} 24 \\ 24 \\ 24 \end{bmatrix}$	24				0
7	28				24				- 6
8	25	$\begin{bmatrix} 23 \\ 26 \\ 23 \end{bmatrix}$	h	$\begin{bmatrix} 24 \\ 24 \\ 24 \end{bmatrix}$	24	$\begin{bmatrix} -4 \\ -4 \end{bmatrix}$	i	$\begin{bmatrix} -2 \end{bmatrix}$	- 4
9	18				24				0
10	38	$\begin{bmatrix} 22 \\ 30 \\ 18 \end{bmatrix}$	a	$\begin{bmatrix} 24 \\ 24 \\ 26 \end{bmatrix}$	24	$\begin{bmatrix} -8 \end{bmatrix}$			- 8
11	14				25				+12
12	23			$\begin{bmatrix} 25 \\ 24 \\ 24 \end{bmatrix}$	24			$\begin{bmatrix} +6 \\ +6 \end{bmatrix}$	+10
13	23				24		b	$\begin{bmatrix} +6 \\ +6 \end{bmatrix}$	+ 6
14	27			$\begin{bmatrix} 23 \\ 25 \end{bmatrix}$	25			$\begin{bmatrix} +6 \end{bmatrix}$	0
15	28				26	$\begin{bmatrix} -2 \end{bmatrix}$	g		- 2
16	25			$\begin{bmatrix} 26 \\ 26 \end{bmatrix}$	26				0
17	32				25				0
18	17	$\begin{bmatrix} 26 \\ 23 \end{bmatrix}$	e	$\begin{bmatrix} 25 \\ 25 \end{bmatrix}$	25	$\begin{bmatrix} +12 \\ +12 \end{bmatrix}$	f	$\begin{bmatrix} +2 \end{bmatrix}$	+14
19	21	27			26				+12
20	32	$\begin{bmatrix} 26 \end{bmatrix}$			26				0
21	24				25				0
22	19	$\begin{bmatrix} 21 \\ 15 \\ 8 \end{bmatrix}$	k	$\begin{bmatrix} 25 \\ 20 \\ 14 \\ 9 \end{bmatrix}$	20			$\begin{bmatrix} -2 \\ -2 \end{bmatrix}$	- 2
23	19				14	$\begin{bmatrix} -4 \end{bmatrix}$	l		- 6
24	6				9				0
25	4				4				0
26	0				0				0
	496				496				

Station intervals, 34 feet. Ordinates in hundredths of feet.

Note that, in the solution shown, D varies from $2^{\circ} 24'$ to $2^{\circ} 36'$ —too small an irregularity to impair seriously the riding qualities of the curve. The spirals are nearly perfect, the ordinates having a common difference of 5 and 6. The length of spiral is about 153 ft, limiting the speed to 50 mph.

Throws are required at only 12 stations, and the maximum throw is only 0.14 ft.

SECOND METHOD OF COMPUTATION

360. When it is desired to obtain a more perfect curve, or to increase the limiting speed on the curve by lengthening the spirals or reducing D , or where the throws are limited, the complexity of the problem often makes it necessary to use a more direct method of computation than that given by the *first method*.

It is possible to choose in advance a set of desired ordinates and then to compute the throws necessary to produce these ordinates, making such adjustments as are necessary to comply with *rules II* and *III*. The desired ordinates may be first chosen by approximate computations, but a graphical method is recommended.¹ Both are explained in **Example 3**.

At any station the measured ordinate minus the ordinate desired will be called the *error*.

TABLE D

Sta.	Error	Resulting Changes			Required Throws	Required Half-Throws
1	a	$-a$				
2	b	$+2a$	$-2a-b$		$+2a$	a
3	c	$-a$	$+4a+2b$	$-3a-2b-c$	$+4a+2b$	$2a+b$
4	d		$-2a-b$	$+6a+4b+2c$	$+6a+4b+2c$	$3a+2b+c$
5	e			$-3a-2b-c$	$+8a+6b+4c+2d$	$4a+3b+2c+d$
					etc.	etc.

¹ Suggested by Rev. J. C. McCoy, Lebanon, Ohio.

Table D. Let the *errors* for the first stations on any curve be a, b, c, d , etc. In order to cancel the error a at station 1, a throw of $2a$ must be applied at station 2. This changes the error at station 2 to $b+2a$ and at station 3 to $c-a$. To cancel the new error at station 2, a throw of $4a+2b$ must be applied at station 3, etc., as shown.

But note that, adding the errors cumulatively to and including the error at each station, we have

Station	Error Sums
1	a
2	$a+b$
3	$a+b+c$
4	$a+b+c+d$
5	etc.

Again adding cumulatively these error sums to, *but not including*, the error sum at each station, we have

Station	Results
1	
2	a
3	$2a+b$
4	$3a+2b+c$
5	$4a+3b+2c+d$
	etc.

The resulting expressions are equal to *one-half the required throws*. Note Table D "*required half-throws*." It is thus possible:

1. To compute directly the required throw.
2. To determine the effect of any particular error on any designated throw.

Table E. When these principles are applied to example in Table A, Table E results. Arrows indicate the direction of the additions.

As is shown later, it is usually necessary to change some of the throws, after the first computation (or trial) has been completed. From Table D the following rule is evident:

Rule V. *Any change in an error will change any subsequent half-throw an amount equal to the product of that change and the difference found by subtracting the station of the error from the station of the half-throw.*

Expressed in an equation:

$$C_T = C_E(S_T - S_E) \quad (328)$$

when C_T = change in half-throw

C_E = change in error

S_T = station of half-throw

S_E = station of error

TABLE E

Sta.	Measured Ordinates	Required Ordinates	Errors	Error Sums	Half-Throws
1	0	0	0	0	0
2	2	1	+1	+1	0
3	3	5	-2	-1	+1
4	12	9	+3	+2	0
5	10	13	-3	-1	+2
6	12	13	-1	-2	+1
7	13	13	0	-2	-1
8	14	9	+5	+3	-3
9	2	5	-3	0	0
10	1	1	0	0	0
11	0	0	0	0	0

TABLE F

Sta.	Measured Ordinates	Required Ordinates	Errors	Error Sums	Half-Throws
1	0	0	0	0	0
2	2	(2)	0	0	0
3	3	5	-2	-2	0
4	12	9	+3	+1	-2
5	10	(12)	-2	-1	-1
6	12	13	-1	-2	-2
7	13	(12)	+1	-1	-4
8	14	9	+5	+4	-5
9	2	5	-3	+1	-1
10	1	(2)	-1	0	0
11	0	0	0	0	0

Table F presents a computation for the same curve as shown in Table E. Four *required ordinates* have been changed as indicated by circles. Note the changes in *errors* which result.

The direct computation of the change in a *half-throw* by equation 328 is illustrated below for station 8. At station 8 the *half-throw* of -3 in Table E has been changed to -5 in Table F, a change of -2 .

By equation 328:

$$(-1)(8-2) = -6$$

$$(+1)(8-5) = +3$$

$$(+1)(8-7) = +1$$

$$\text{Sum} = -2$$

To comply with *rule II*, changes in errors are usually introduced in pairs of equal quantities but with opposite signs, as in Table F.

Equation 328 can then be modified as follows:

$$C_T + C_{T'} = C_E(S_{E'} - S_E) \quad (329)$$

The change in *half-throw* at station 11 equals zero and may be computed thus:

$$(-1)(5-2) = -3$$

$$(+1)(10-7) = +3$$

$$\text{Sum} = 0$$

361. Example 3. Assume that it is necessary to align the curve shown in Table C to permit a speed of 55 mph and that no throw of over 0.6 ft is to be used.

From Table XXXIII, for a $2^\circ 30'$ curve, a spiral of 180 ft or 5.3 stations is required. The following ordinates give a spiral of this length: 3, 7, 11, 15, 19, 23.

The sum of the measured ordinates is 496, to be divided among 26 stations. The two spirals account for 156 and 12 stations, leaving 340 and 14 stations for the curve proper, that is, 10 stations of 24 and 4 stations of 25.

Instead of the desired ordinates being computed, they may be obtained graphically (Fig. 189). The measured ordinates are plotted. The curve is then represented by straight lines which strike an average of the measured ordinates. The horizontal line represents a circular arc, and the sloping lines, the

spirals. The steepness of the slope between any two ordinates represents a measure of the shock to the train. As the circular arc should be as long as possible, the spirals should be straight lines which reach the ordinate of the main curve as quickly as possible with the minimum slope. The number of stations included in the spiral should be close to the value necessary to make the spirals the required length.

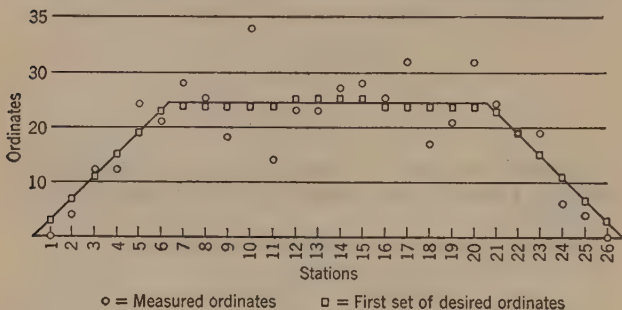


FIG. 189.

After lines are drawn, the *desired ordinates* are chosen by selecting points for each station which fall on or as near to the line as possible. After the first choice, no further use is made of the diagram.

Table G shows complete tabulation of the computation. Three trials were necessary, listed under columns *A* for the first trial, columns *B* for the second trial, and so on.

Trial A. The *required ordinates* were set up according to the foregoing explanation. This arrangement resulted in a *half-throw* of +1 at station 26, violating *rule III*.

Trial B. By equation 329, $C_T + C_{T'}$ must be introduced equal to -1 for station 26. If C_E of -1 is introduced at any station, and at the next station $C_{E'}$ of +1 is introduced, *rules II* and *III* will be satisfied. These changes may be placed at any point on the curve. Stations 11 and 12 are probably the best locations, and, by equation 329,

$$(-1)(12-11) = -1$$

The complete results are tabulated in columns *B*.

TABLE G

Stations	Measured Ordinates			Required Ordinates			Errors			Error Sums			Half-Throws		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1	0			3			-3			-3			0		
2	4			7			-3			-6			-3		
3	12			11			+1			-5			-9		
4	12			15			+3			-8			-14		
5	24		18	19			+5		+6 (a)	-3		-2	-22		
6	21		22	23			+2		-1 (b)	-5		-3	-25		
7	28			24			+4			-1			-30		-24
8	25			24			+1			0			-31		-27
9	18			24			+6			-6			-31		-26
10	38			24			+14			+8		-4	-31		-24
11	14		25	24			-10		-2 (a)	-2		-3	-29		-28
12	23	25		25	24		-2	-11		-4	-3	1	-31	-32	-18
13	23			25			+2	-1		-6		-5	-35	-36	-19
14	27			25			+2			-4		-3	-41	-42	-22
15	28			25			+3			-1		0	-45	-46	-27
16	25		25	24			+1		0 (b)	0		0	-46	-47	-30
17	32		25	24			+8		+7 (c)	+8		+7	-46	-47	-30
18	17		25	24			+7		-8 (d)	+1		-1	-38	-39	-23
19	21		25	24			+3		-4 (e)	-2		+5	-37	-38	-24
20	32		25	24			+8		+7 (f)	+6		+2	-39	-40	-29
21	24		22	23			+1		+2 (g)	+7		+4	-33	-34	-27
22	19		18	19			0		+1 (c)	+7		+5	-26	-27	-23
23	19		14	15			+4		+5 (d)	+11		+10	-19	-20	-18
24	6		6	11			+5			+6		+5	-8	-9	-8
25	4		6	7			+3		-2 (e)	+3		+3	-2	-3	-3
26	0			3			-3			0		0	+1	0	0
	496			496											

Station intervals, 34 feet. Ordinates in hundredths of feet.

Trial C. But the requirement of a maximum throw of 0.6 ft limits the *half-throws* to 30. At station 16 the *half-throw* is -47 , requiring a change of $+17$.

The changes were introduced where they caused the least disturbance to the curve, and the computations are listed here. a and b introduce the required change of $+17$ previous to station 16, and c , d , e , and f compensate, following station 17, bringing the throw at station 26 back to zero.

$$\begin{array}{rcl}
 a & (+1)(12-5) & = + 7 \\
 b & (+1)(16-6) & = +10 \\
 c & (-1)(22-17) & = - 5 \\
 d & (-1)(23-18) & = - 5 \\
 e & (-1)(25-19) & = - 6 \\
 f & (-1)(21-20) & = - 1 \\
 & \hline
 \text{Sum} & = & 0
 \end{array}$$

The maximum *half-throw* is now 30, D varies between $2^\circ 24'$ and $2^\circ 30'$, and the spiral interval is 4 except between stations 4 and 5, and 24 and 25. These variations are too small to damage the riding qualities of the curve.

362. Example 4. In Table H, a further solution is shown. The required ordinates have been chosen to sharpen the curve at the center and thus reduce the center minus throws.

363. Example 5. A slightly modified computation is illustrated in Table I, particularly applicable to long curves. The requirements are 60 mph and maximum throw 0.6 ft.

Trial A. A proper spiral is introduced and the *half-throws* determined through station 14. To continue trial A is unnecessary.

Trial B. The *half-throws* are too large from station 9 to 14; so minus error changes are introduced at the beginning of the curve at stations 0 through 5 and then balanced at stations 10 through 13 and trial continued through station 19.

$$\begin{array}{rcl}
 a & (-1)(10-0) & = -10 \\
 & (-1)(11-1) & = -10 \\
 & (-1)(12-2) & = -10 \\
 & (-1)(13-3) & = -10 \\
 & (-1)(13-4) & = - 9 \\
 & \hline
 \text{Sum} & = & -49
 \end{array}$$

TABLE H

Stations	Measured Ordinates	Required Ordinates		Errors		Error Sums		Half-Throws	
		A	B	A	B	A	B	A	B
1	0	2		- 2		- 2		0	
2	4	6		- 2		- 4		- 2	
3	12	10		+ 2		- 2		- 6	
4	12	14		- 2		- 4		- 8	
5	24	18		+ 6		+ 2		-12	
6	21	22		- 1		+ 1		-10	
7	28	25		+ 3		+ 4		- 9	
8	25	25		0		+ 4		- 5	
9	18	25		- 7		- 3		- 1	
10	38	25		+13		+10		- 4	
11	14	25		-11		- 1		+ 6	
12	23	25	26	- 2	-3a	- 3	- 4	+ 5	
13	23	26	25	- 3	-2a	- 6		+ 2	+ 1
14	27	26		+ 1		- 5		- 4	- 5
15	28	25		+ 3		- 2		- 9	-10
16	25	25		0		- 2		-11	-12
17	32	25		+ 7		+ 5		-13	-14
18	17	25		- 8		- 3		- 8	- 9
19	21	25		- 4		- 7		-11	-12
20	32	25		+ 7		0		-18	-19
21	24	22		+ 2		+ 2		-18	-19
22	19	18		+ 1		+ 3		-16	-17
23	19	14		+ 5		+ 8		-13	-14
24	6	10		- 4		+ 4		- 5	- 6
25	4	6		- 2		+ 2		- 1	- 2
26	0	2		- 2		0		+ 1	0
	496	496							

Station intervals, 34 ft. Ordinates in hundredths of feet.

$$a \quad (-1)(13-12) = -1$$

Trial C. The *half-throw* at station 19 is now too large (-33); hence:

$$b \quad (+1)(19-9) = +10$$

Trial D. The *half-throw* at station 22 must be changed by +22 and at station 27 by +30.

TABLE I

Sta- tions	Measured Ordinates	Required Ordinates				Errors				Error Sums				Half-Throws			
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0	0																
1	0	3	1			-3	-1			-3	-1			0	0		
2	4	6	4			-2	-4			-5	-5			-1	-1		
3	12	9	7			+3	-3			-5	-8			-3	-6		
4	12	12	10			0	+2			-2	-6			-8	-14		
5	24	15	13			+9	-1			+7	-7			-10	-20		
6	21	18				+3				+2	+2			-12	-27		
7	28	21				+7				+17	+5			-25	-20		
8	25	24				+1				+18	+13			-5	-25		
9	18	27				-9				+9	+4			+5	-20		
10	38	28		26		+10				+19	+15	+5		+22	-8		
11	14	28	27			-14	+11	-8 ^b		+5	+16			+40	+5		
12	23	28	27			-5	-13			+3	+3			+49	+9	+10	
13	23	28	27			-6	-4			0	+2			+68	+24	+26	
14	27	29	27			-	-4			-6	-6			+73	+24	+29	
15	28	29		27			-2		0 ^c		-8			+67	+18	+23	+18
16	25	28					0				-8				+10	+16	+13
17	32	28					-3		+5 ^d		-11				+2	+9	+5
18	17	27					+4				-7				-9	-1	
19	21	24					-10		-9 ^e		-17				-16	7	+2
20	32	21						-3 ^b							-33	-23	-10
21	24	18						+11	+10 ^c							-42	-25
22	19	15						+6	+5 ^c							-50	-30
23	19	12						+4								-52	-30
24	6	9						+7								-50	-26
25	4	6						-2	-3 ^d							-41	-15
26	0	3						-3								-35	-7
27	0							-1	-2 ^c							-31	-2
	496	496		1	2											-30	0

Station intervals, 30 feet. Ordinates in hundredths of feet.

	At station 22	At station 27
c	$\{ \begin{aligned} (+1)(20-14) &= +6 \\ (+1)(21-14) &= +7 \end{aligned}$	$\{ \begin{aligned} (+1)(20-14) &= +6 \\ (+1)(21-14) &= +7 \end{aligned}$
d	$(+1)(22-17) = +5$	$(+1)(25-17) = +8$
e	$(+1)(22-18) = +4$	$(+1)(27-18) = +9$
	Sum = +22	Sum = +30

The curve has been extended one station on each end to provide the longer spirals required.

APPLICATION TO SIDINGS

364. Curves in yards and sidings are usually laid out with a *minimum radius* to economize space. Upon the development of sharp spots in such curves or the introduction of a new type of locomotive, derailments can be expected. Usually the *middle flangeless drivers* drop off *inside* the curve of the rails.

The elimination of these sharp spots or the lengthening of the radius throughout can most easily be accomplished by string lining methods.

As on main-line track, spirals should be introduced in yards where space permits. Often, however, yard curves can have no spirals, which require longer and sharper curves and, therefore, extra space. Also, *reversed curves* can be introduced at the ends of yard curves sometimes to great advantage.

Table J illustrates a yard curve with station 1 at the heel of a frog and station 14 at the beginning of a body track. The stations have been laid off in sections equal to one-half the wheel base of the locomotive. Either the width of the flangeless drivers or experience on other curves indicates that a middle ordinate of more than 0.15 ft will cause derailment.

Trial A. The ordinate at station 1 cannot be changed without interfering with the ladder. Thereafter the ordinates should be 15.

At some point between stations 13 and 14, *rule II* is satisfied as indicated by the *error sums* changing sign. But since the *half-throws* are still plus, the curve is continued until a minus *half-throw* appears at station 18.

Trial B. A reversed curve (giving minus ordinates) is necessary to satisfy *rule II* and is introduced, making station

TABLE J

Stations	Measured Ordinates	Required Ordinates			Errors			Error Sums			Half-Throws		
		A	B	C	A	B	C	A	B	C	A	B	C
1	12	12			0			0			0		
2	12	15			- 3			- 3			0		
3	17	15			+ 2			- 1			- 3		
4	13	15			- 2			- 3			- 4		
5	15	15			0			- 3			- 7		
6	21	15			+ 6			+ 3			-10		
7	22	15			+ 7			+10			- 7		
8	14	15			- 1			+ 9			+ 3		
9	15	15			0			+ 9			+12		
10	21	15			+ 6			+15			+21		
11	17	15			+ 2			+17			+36		
12	18	15			+ 3			+20			+53		
13	3	15			-12			+ 8			+73		
14	0	15			-15			- 7			+81		
15		15			-15			-22			+74		
16		15	0	+ 5	-15	0	- 5a	-37	-22	-27	+52		
17		0	-15	- 7	0	+15	+ 7b	-37	- 7	-20	+15	+30	+25
18			- 7	-15		+ 7	+15b		0	- 5	-22	+23	+ 5
19				- 5			+ 5a			0		+23	0
20											+23		0
	200		200	200									

16 P.R.C. This still violates *rule III* by leaving a +23 at the end of the curve.

Trial C. *Rule III* is satisfied by changes *a* and *b*.

$$a \quad -5(19-16) = -15$$

$$b \quad -8(18-17) = -8$$

$$\text{Sum} = -23$$

The P.R.C. now falls at a point between stations 16 and 17.

Note. When a curve is reversed, the algebraic difference of adjacent ordinates must never be greater than the maximum single ordinate allowed, because, when the string extends across the P.R.C., the ordinates are really measured to sub-chords and, hence, must be made to vary approximately as

the lengths of the subchords in order to secure uniform curvature.

In Table J the required ordinates, column C, stations 16 and 17, are +5 and -7. The algebraic difference is $+12 < +15$

365. Combination of the two methods. Rules can be deduced from the second method which facilitate the use of the first method. For example: *Any set of changes in ordinates can be made if they are uniform in sign, size, and location about a central point and their sum is zero.* Thus:

Station	Error	Error Sums	Half-throws	Throws
6	-2	-2	0	0
7	0	-2	-2	-4
8	+3	+1	-4	-8
9	-1	0	-3	-6
10	-1	-1	-3	-6
11	+3	+2	-4	-8
12	0	+2	-2	-4
13	-2	0	0	0

SETTING POINTS FOR NEW ALIGNMENT

366. Several methods are employed marking the new position of the track. Figure 190 illustrates the method recommended. The stakes should be of hard wood between $1\frac{1}{2}$ and 2 in. square and 18 in. long.

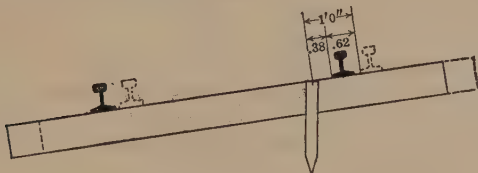


FIG. 190.

At the particular station shown, a plus throw of 0.62 ft is required. The stake is set flush with the base of the rail, and the center of tack is set 0.38 ft from the inside edge of the base so that, when the track is properly thrown, the base of rail will be $1' - 0''$ from the tack. For a minus 0.62 throw the tack would be set 1.62 ft from the rail base. Before the tacks are set, the *half-throws* should be converted to *throws* and the resulting distances from base of rail computed. Instead of $1' - 0''$ any other distance can be used but preferably an even foot or half-foot for simplicity. This method is quick, accurate, and easy for the track foreman to use.

Stakes are sometimes set at the new center line. An awkward computation is then necessary, and the measurements must be made from gauge—a difficult procedure.

When stakes must be set in hard ballast, a lining bar should first be driven to make a hole for the stake. Setting stakes may be avoided by measuring from adjoining track. A square wooden pole marked on four faces at each end is supplied the foreman. He throws the track to the particular mark for the station.

CHAPTER XVIII

THEORY OF MAXIMUM ECONOMY IN GRADES AND CURVES

367. Choice of routes. Before commencing the field work of location, the engineer must decide which of the surveyed routes shall be adopted. He must also establish the maximum grade in each direction and the minimum radius of curve on that route.

The general considerations which guide the engineer in the selection of one of several routes for location are mentioned in the chapter on reconnaissance, but upon the completion of the preliminary surveys he has at hand a large amount of information which enables him to consider this important question much more in detail. Unless his instructions are explicitly to the contrary, he may assume it to be his duty to find the *best line*, or that one which, for a series of years following the completion of the road, will require the least annual expense, including interest on first cost. The finances of the company may be so limited as not to permit the construction of the best line at once, and it may then be the duty of the engineer to select the *cheapest line*, or that of least first cost, as a temporary expedient, with the expectation of building the road at its best when the improved credit of the company will permit. But generally he will be able to build the cheaper portions of the best line at once, only making deviations and introducing heavier grades at the expensive points to avoid a cost beyond the present means at his command. The selection of the best line may be a choice between different routes or between different grades and curves on the same route. The latter case is considered first.

368. To solve the problem of true economy we must determine both the actual costs of building the line and the expenses of operating it at a given maximum grade, and also what

changes will be made in these expenses by a change in that maximum. We have then, on one hand, the annual interest on the original cost and, on the other, the annual expense of operating the road. *The best grade is that which will render the sum of these two a minimum.* Both forms of expense consist of two parts: one that is affected by a change in grade, and the other that is not. Clearly the former is the only one we have to consider in either, since, when the sum of the variable portions is a minimum, the sum total will be a minimum also. The varying portions then are functions of the grade, though independent of each other. If, therefore, z' represents the maximum grade in feet per mile, and x represents the corresponding value of that portion of the annual expense which varies with the grade, the relation existing between the two is $x = f(z')$. Similarly, if y represents the interest on so much of the first cost as is affected by grade, $y = f'(z')$. The problem then is to find that value of z' which shall render

$$x + y = a \text{ minimum}$$

The expression represented by $x = f(z')$ will now be developed.

The elements that enter into this expression are numerous and will be considered in succession.

369. The tractive force of a locomotive is limited by the friction existing between the driving wheels and rails, since a locomotive is designed to have its boiler and cylinder capacity somewhat in excess. This friction, called the adhesion, is expressed as a percentage of the weight on the driving wheels and under ordinary working conditions is found to be 20 to 25% of the weight. The weight imposed by the driving wheels is limited by the ability of the rail material to withstand abrasion and deformation; with iron rails the limit per pair of drivers is fixed at 24,000 lb with steel rails at 48,000 lb. There are instances of 52,000 lb permitted.

370. The expense of running an engine one mile, hauling a train on the proposed road, can be estimated only from the experience on other roads similarly situated. The items of expense while the train is on the road are fuel and the wages of the engineer and the train crew, together with many smaller items of transportation.

As previously stated, when lines of different *length* are to be compared for expense per train-mile, it is only those items affected by grade which concern us in this problem.

The cost of a train-mile has been increasing for some years past. An average figure may be \$1.50, and the part affected by the ruling grade is about 52 per cent of this amount.

Where the bulk of traffic warrants their use, heavy locomotives give more economical results than lighter ones.

371. The resistance offered to the motion of a railway train is occasioned by a variety of causes, concerning which a great deal of uncertainty exists as to their relative effect. An investigation which should seek to determine the exact amount of each partial resistance and, then, by a summation, derive the total, would be tedious and, in the present state of our knowledge, unsatisfactory. We shall therefore simply group the resistances under three general heads, namely:

Resistance due to uniform motion on a straight level track.

Resistance due to grade.

Resistance due to curvature.

372. The first of these, considered as an aggregate of the various items of friction in locomotive and train, of oscillations and impacts, and of resistance of the atmosphere, is found to vary nearly or quite as the square of the velocity. The friction of a locomotive is greater in proportion to its weight than that of a car, owing to its many moving parts, so that the resistance of a short train is greater in proportion to its total weight than that of a long train. The resistance of the atmosphere is greater also in proportion to the weight of a short train than of a long one. An empty train will offer more resistance in proportion to its weight than a loaded one. A formula which shall express the resistance of a train to uniform motion must include at least the velocity and the weight of the train and locomotive.

The following empirical formula was given in the earlier editions of this book. It is based on the records of a large number of experiments and is designed to give the resistance per ton for all trains, whether freight or passenger, and at any velocity, under ordinary circumstances. Accidental circumstances, such as the state of the weather, and the condition of the roadbed, rails, and rolling stock, may largely

modify the resistance, but these, of course, are not taken into account in the formula.

$$q = 4.82 + \left(0.0053 + \frac{0.000478E^2}{E + W + T} \right) V^2 \quad (330)$$

where V = the velocity of the train in miles per hour, E = the weight of the engine and tender in tons, W = the weight of cars in tons, T = the weight of freight in tons, and q = the resistance to uniform motion in pounds per ton. The short ton of 2000 lb is used.

An elaborate series of experiments¹ on train resistance has been conducted by Professor E. C. Schmidt of the University of Illinois. The tests covered a wide range of velocities, weights, and loadings of trains. Formulas were developed for several different loadings. The following single empirical formula expresses the value of the train resistance in pounds per ton:

$$q = \frac{V + 39.6 - 0.031w}{4.08 + 0.152w} \quad (331)$$

where w = the average weight of car and load in tons, and V and q are as in equation 330.

373. The second resistance considered is that due to gravity in grades. It varies in the exact ratio of the rise to the length of the grade.

Let G_s = rise of grade in feet per station

G_m = rise of grade in feet per mile

q' = resistance in pounds per ton due to grade

Then,

$$\left. \begin{aligned} q' &= 2000 \frac{G_s}{100} = 20G_s \\ \text{and} \quad q' &= 2000 \frac{G_m}{5280} = \frac{1}{2.64} G_m \end{aligned} \right\} \quad (332)$$

The first of these equations expressed in words is easily remembered. *The grade resistance is equivalent to 20 lb per ton per rate of grade per station.*

¹ See Bulletins 43 and 59 of the Engineering Experiment Station of the University of Illinois; also Journal of the American Society of Mechanical Engineers for May and September 1910.

374. The third resistance considered is that due to curvature of the track. This resistance is due to the friction of the wheels on the top of the rail and of their flanges on the side of the rail. The top friction is lateral, owing to the oblique position of the wheel on the rail, and longitudinal, owing to the greater length of the outer rail, since both wheels are rigidly attached to the axle. The flange friction is due to the reaction of the top friction, which, combined with the parallelism of the axles, throws the truck into an oblique position on the track. A forward flange presses the outer rail, while a rear flange is usually in contact with the inner rail. The centrifugal force of the car will increase the pressure on the outer rail, unless the ties are inclined at an angle sufficient to counterbalance this force. But, if the ties are inclined too much or the velocity is less, the pressure on the inner rail will be increased. An uneven track will cause the truck to pursue a zigzag course, increasing the resistance considerably.

The curve resistance probably varies from about $\frac{1}{2}$ to 1 lb per ton on a 1° curve. For sharper curves it varies as the degree of curve. The value depends on the character of the rolling stock, the location of the curve with respect to grade, and the speed of the train.

375. Curve compensation. When a ruling grade is lessened for curvature, it is said to be *compensated for curvature*, or merely *compensated*, and the equivalent grade resistance per degree of curve is called the *rate of compensation*.

To ascertain the relation between the curve and the grade resistance, the following reasoning may be employed:

Assuming the *rate of compensation* as 0.035 and that the curve resistance varies directly as the degree of curve, we have

$$\text{and} \quad \left. \begin{array}{l} 0.035D = G_s \\ 1.847D = G_m \end{array} \right\} \quad (333)$$

For definition of degree of curve, see § 78.

Then, if q'' = the curve resistance in pounds per ton on any curve, by combining first equations 332 and 333 and substituting q'' for q' results in

$$q'' = 0.70D \quad (334)$$

The coefficient of D in equation 333 is adopted as an average of values suggested in the recommendations quoted below.

Compare also the latter part of § 374.

Example. If the ruling grade of a road is 1%, what is the allowable grade on a 4° curve?

From first equation 333 the additional resistance caused by the 4° curve is equivalent to 0.14 ft per station. Consequently, the 1.0% grade must be lowered to 0.86%.

The American Railway Engineering Association has made the following recommendations for the rate of compensation:

- (a) Compensate 0.03 per degree:

When the length of curve is less than half the length of the longest train.

When a curve occurs within the first 20 ft of rise of a grade.

When curvature is in no sense limiting.

- (b) Compensate 0.035 per degree:

When curves are between one half and three quarters as long as the longest train.

When the curve occurs between 20 and 40 ft of rise from the bottom of the grade.

- (c) Compensate 0.04 per degree:

Where the curve is habitually operated at low speed.

Where the length of the curve is longer than three quarters of the length of the longest train.

Where elevation is excessive for freight trains.

At all places where curvature is likely to be limiting.

- (d) Compensate 0.05 per degree wherever the loss of elevation can be spared.

376. Maximum trains. It is evident that grades and curves, by their resistances, fix a limit to the weight of a train which a given engine can haul over them.

To find an expression for the maximum train which a given locomotive can haul over a given compensated grade:

Let P = the drawbar pull of the locomotive in pounds

T' = weight of paying load in tons per maximum train

W' = weight in tons of cars carrying the load T'

Then, for uniform motion at a given velocity,

$$(W' + T')(q + q') = P \quad (335)$$

Let t = the average load of one car in tons, and w = the average weight of one car including load in tons. The number of cars n , all assumed loaded to the average, will then be T'/t .

Then, $W' + T' = nw = wT'/t$, and, substituting in equation 325, we derive

$$T' = \frac{t}{w} \left(\frac{P}{q + q'} \right) \quad (336)$$

In this equation q = the resistance per ton due to uniform motion, q' = the resistance per ton due to the *maximum grade* opposed to the direction of the train.

For accelerated motion the reaction of inertia of the train must be added to these resistances. This is estimated at $\frac{1}{2}q$, in order that a train starting from the rest may acquire the requisite maximum velocity, even on a maximum grade, in a reasonable time, say from 3 to 6 minutes. Therefore, for accelerated motion,

$$T' = \frac{t}{w} \left(\frac{P}{\frac{3}{2}q + q'} \right) \quad (337)$$

The value of q in equation 331 may be substituted in equation 337, and we obtain

$$T' = \frac{t}{w} \left[\frac{P}{\frac{3}{2} \left(\frac{V + 39.6 - 0.031w}{4.08 + 0.152w} \right) + q'} \right] \quad (338)$$

Also, for the weight of maximum train and load,

$$W' + T' = \left[\frac{P}{\frac{3}{2} \left(\frac{V + 39.6 - 0.031w}{4.08 + 0.152w} \right) + q'} \right] \quad (339)$$

which is the expression required.

When there is no grade, q' becomes zero; hence, for a level track equations 337 and 338 become

$$T_0' = \frac{t}{w} \frac{2P}{3q} \quad (337A)$$

$$T_0' = \frac{t}{w} \frac{P}{\frac{3}{2} \left(\frac{V + 39.6 - 0.031w}{4.08 + 0.152w} \right)} \quad (338A)$$

where T_0' = the weight of paying load in tons per maximum train on a level grade.

377. An engine stage is a division of the road to which a locomotive is limited and over which it regularly hauls a train. Its length varies, on existing roads, from 50 to 200 miles or more, depending on the grades, on the length of the whole line, and on the distance between points favorable for the location of shops, and so on. The average engine stage on American roads is not far from 100 miles. If there are to be several engine stages on the proposed line, the problem of maximum economy of grade must be solved with reference to each of them separately.

Let L = length of engine stage in miles

e = that part of the expense per train-mile which varies with grade (in dollars)

A = average annual paying freight in tons moving in one direction

a = average annual paying freight in tons, moving in the opposite direction; and, if these are not equal, let A be greater than a . Now T' , equation 338, is the maximum train load which, at a velocity V , should be hauled up steepest grade z' , opposed to the direction of the tonnage A . Hence, A/T' = the number of trains per year; and, since each train must go and return, $\therefore 2LA/T' =$ the total train mileage per year.

If there were no return tonnage, the annual expense chargeable to A would be $2ALe/T'$, but, since some of the cars return loaded with the freight a , these are not chargeable to A and must be deducted from the foregoing expression. Hence, if we denote the annual expense of engine mileage by x ,

$$x = \frac{(2A - a)Le}{T'} \quad (340)$$

in which the value of the maximum grade z' is involved in the value of T' .

But we may obtain an expression for x in terms of z' ; for, at any given velocity, the resistance q_0 on a level is equal to the resistance due to a certain grade z_0 , the value of which

is, by equation 331, for uniform motion,

$$z_0 = 2.64q_0$$

So the resistance q to motion up a grade z' is equal to the resistance due to some grade $z = 2.64q$, the total resistance being that due to the combined grades $z + z'$. Now, since the gross weight of a maximum train, under a constant engine power, is inversely as the resistances, we have, for conditions of accelerated motion:

$$\frac{w}{t}T' : \frac{w}{t}T_0' :: \frac{3}{2}z_0 : \frac{3}{2}z + z'$$

whence

$$T' = \frac{T_0' z_0}{z + \frac{2}{3}z'} \quad (341)$$

in which T_0' = maximum train load on a level line. Substituting this value of T' in equation 340 we have

$$x = \frac{z + \frac{2}{3}z'}{T_0' z_0} (2A - a) Le \quad (342)$$

which is the complete expression for $x = f(z')$ required.

378. Graphical solution. Could we also find a complete expression for $y = f'(z')$, we might then proceed to find, by analysis, that value of z' which would render $x + y = a$ minimum. But the value of y cannot be formulated, since it depends on the accidental features of the country through which the line passes; it can only be determined for any given value of z' by an estimate based on the survey. We, therefore, resort to a graphical solution.

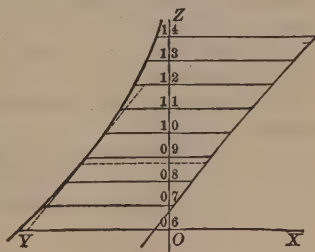


FIG. 191.

Equation 342 is the equation of a curve in the plane ZX , Fig. 191. If we assume several values of z' and calculate the corresponding values of x , we may lay these off by scale on the axes of Z and X , respectively, and so obtain several points

through which the curve of annual expense may be drawn. We then make estimates of the cost of constructing the road at the same values of z' , and, taking the annual interest of each estimate as an ordinate y to OZ in the plane ZY , we lay it off to scale at the proper height, thus obtaining a series of points in the plane ZY , through which the curve of annual interest on first cost may be drawn. If now we suppose the plane ZY to be revolved to the left about the axis OZ until it coincides with the plane OX , as in Fig. 191, we shall see that the two curves are convex to OZ and to each other. The shortest horizontal line intercepted by them indicates the minimum value of $(x+y)$, and the point where this line cuts the axis OZ indicates the corresponding value of z' , which is the one required. If tangents be drawn to the curves at the points where the shortest horizontal line intersects them, the tangents will be parallel to each other. Any convenient scales may be used to lay off the values of z' and x , provided that the values of x and y be laid off to the *same scale*. It is well to reduce all the values of x by an amount common to them all, and the same with respect to values of y , before laying them off to scale. This will bring the two curves nearer together without altering their form.

379. To facilitate the calculation of x , a table might be computed giving values of $1/T'$ for several locomotives and based on equation 338.

The value of x can be found by multiplying the reciprocal of T' by $(2A - a)Le$.

The data for a single locomotive and train will be taken as follows:

$$t = 30 \text{ tons of freight per car load}$$

$$w = 45 \text{ tons per car and load}$$

$$V = 12 \text{ miles}$$

$$P = 20,000 \text{ lb}$$

Substituting these values in equation 338 and assuming different rates of grade, we can find the maximum loads of freight which the locomotive can haul up these grades. Further data and a complete solution of the problem are given in § 381.

380. In the given solution, the grades have been compensated. Grades less than the ruling grade need not necessarily be reduced for the curves on them, unless the sum of the grade and the curve equivalent exceeds the ruling grade.

381. For an *example*, suppose that a certain engine stage is to be 100 miles long, that an estimate of the cost of construction has been made based on a ruling grade of 52.8 ft per mile against the heavier traffic, and that the annual interest on the estimate amounts to \$168,000. Also suppose that the average traffic in one direction is estimated at 375,000 tons per year, and in the other direction at 125,000 tons, and that the part of the train-mile expense due to grade is 80 cents; then, $(2A - a)Le = \$50,000,000$. The most economical ruling grade must now be found.

First, select at least two other possible ruling grades, and, having made an estimate of the cost of constructing the road on each, take the annual interest of each, as in the first case.

Suppose the two ruling grades thus selected to be 73.92 and 31.68 ft per mile, or 1.4 ft per station and 0.6 ft per station, and the interest on the estimates to be \$145,596 and \$204,388, respectively. Then the information may be grouped as in the following table.

G_s	y	$\frac{1}{T'}$	x	$x + y$	z'
1.4	145 596	.....	.....	.....	73.92
1.3	149 886				
1.2	155 050	.0023170	115 850	270 900	63.36
1.1	161 088	.0021673	108 385	269 473	58.08
1.0	168 000	.0020175	100 875	268 875	52.80
0.9	175 786	.0018677	93 385	268 171	47.52
0.8	184 446	.0017180	85 900	270 346	42.24
0.7	193 980				
0.6	204 388	.....	.....	.....	31.68

The values of y in the second column are obtained by interpolating by second differences from the interest on costs of construction of the 1.4, 1.0, and 0.6% grades. T' is obtained from equation 338, the data in § 379 being used. The fourth column is obtained by multiplying $1/T'$ by $(2A - a)Le$, the numerical value of the latter being \$50,000,000. We observe that the values of x and y increase in opposite directions

and that the minimum value of $(x+y)$ will occur on a grade of about 0.9 per station; therefore, this will be the most economical grade for the given conditions. As previously noted, the value of $(x+y)$ will not be the annual outlay of the road, or engine stage, because many items of expense which are independent of the ruling grade are not included in the value of 80 cents per train-mile.

As a general proposition it is advisable to increase the size of locomotives. Certain limitations to increase of size occur, however, such as strength of bridges and the amount of traffic available.

The problem may be pursued further with other locomotives and loadings, in which case it is to be remembered that, as the size of the locomotive increases, the value of e will be changed. Also the velocity may be increased or decreased, and, if this is done, the value of the drawbar pull will change.

382. Pusher grades. Since x (equation 340) varies directly as L , it is important that an engine stage having heavy grades should be short. Its length, however, must be consistent with the economical length of the adjoining engine stages and with the amount of work which a locomotive ought to perform daily. The most favorable condition for a road would be that in which all the engine stages were operated at equal expense. But if, to secure this result, the engine stage of heavy grades must be unreasonably reduced in length, it will be better to adapt the grades to the use of two locomotives per train.

383. Maximum return grades. After the maximum grade z' opposed to the heavier tonnage A has been determined, we have now to consider what is the limit to grades in the opposite direction. The locomotives are supposed to haul their maximum loads in moving the tonnage A , and, since the return tonnage a is less than A , the locomotives in returning will not be worked to their full capacity if they encounter no grades steeper than z' . We, therefore, have a margin of power in the returning locomotives of which we may take advantage in order to cheapen the cost of construction or to shorten the line, by introducing grades steeper than z' against the lighter traffic.

The weight of a maximum train moving up the grade z'

is (equation 339) $W' + T'$; the weight of the train returning will be

$$W' + \frac{a}{A}T' = \left(\frac{w-t}{t} + \frac{a}{A}\right)T'$$

Substituting this in place of $(W' + T')$ (equation 339), and solving for q' , we find the resistance due to a maximum grade opposed to the returning train. Whence, by equation 332, if we let Z = the maximum return grade,

$$Z = 2.64 \left[\frac{P}{\left(\frac{w-t}{t} + \frac{a}{A}\right)T'} \right] \quad (343)$$

Inasmuch as the value of Z varies with every change made in z' , the engineer, when estimating the cost of construction on the basis of any maximum grade of z' , should take care that the return grade of Z nowhere exceeds its limits as given by equation 343. In the example (§ 381), $z' = 52.8$ approximately; hence, $T' = 495.6$ (equation 338). Substituting these values in equation 343, we find that $Z = 127.8$, which is, therefore, the limit for return grades in this case. These grades should, of course, be compensated.

384. Undulating grades. Suppose that 30 miles per hour is a safe maximum velocity for a freight train going down any grade. Assuming that a train starts down a grade at this velocity, we may find the value of the grade which will cause the train to continue at a constant velocity, without the use of steam or brakes.

Designate the value of G_m in equation 332 by z , and we have

$$z = 2.64q$$

If we substitute the value of q from equation 331 in this, and we get

$$z = 2.64 \left(\frac{V + 39.6 - 0.031w}{4.08 + 0.152w} \right) \quad (344)$$

When $V = 30$, this becomes

$$z = 2.64 \left(\frac{30 + 39.6 - 0.031w}{4.08 + 0.152w} \right) \quad (344A)$$

As a speed of 30 miles an hour is considered unobjectionable, the grade z which induces it cannot be so, provided, of course, it does not exceed the values of z' or Z which were found as the most economical. For the extra work done by the engine in ascending one grade, z is utilized in descending the next; and the net result is the same as though the two were replaced by a uniform grade. The engineer, therefore, is not warranted by economic considerations in reducing undulating grades which do not exceed z to a uniform grade, when to do this would cause any increase in the cost of construction, unless z exceeds the grades z' or Z of maximum economy.

385. But, when grades exceed z (equation 344A) the resulting speeds of the maximum train become too great, and the necessary application of the brakes absorbs a portion of the power previously expended in gaining the summit, which is thus worse than wasted, since it increases the wear and tear of machinery and track. Therefore, the engineer is justified in spending a certain sum of money in reducing grades which exceed z to that limit. A calculation of the loss of power due to the use of brakes on a grade and of the cost of that lost power, together with the resulting wear and tear per year, will give the interest on the sum that may be justifiably spent in reducing the grade from its position of cheapest construction.

386. The limit z is not constant but depends on the weight of the maximum train, which, in turn, depends on z' . It will not be the same in both directions unless $A = a$, giving $z' = Z$. In the example (§ 381), $W' + T' = 743.4$. Hence, (equation 344A) $z = 16.24$ descending in the direction of the traffic A . Also, $W' + (a/A)T' = 413.0$, whence $z = 23.04$ descending in the opposite direction. These are the limits in this case at which undulating grades cease to be profitable.

387. Comparison of routes. We have finally to consider the method for selecting the best line from several proposed routes. For this purpose we determine the most economical grade on each route thought worthy of consideration, calculate the interest on the *entire cost* of constructing the line with that ruling grade and also the *annual expense* of operating the line, and take the sum of the two. That route is best in respect to which this *sum* is the least.

388. The value of saving 1 mile in distance on any route is found by dividing the sum of the annual operating expense

and the interest on the cost of construction by the rate of interest, and the quotient by the length of the line in miles.

389. Conclusions. We have now fully discussed the theory and developed the formulas necessary to the determination of the most economical grades; but the value of the results in a given case depends on the correctness of the engineer's estimates which enter into the formulas. These may seldom prove precisely accurate, yet, if he can bring them within definite limits, he may determine the grades of maximum economy within corresponding limits. But in the case of a railroad already finished and in full operation, where the elements of first cost, of the existing traffic and of the operating expenses are fully known, an investigation by means of the foregoing formulas furnishes a critical test as to the economy of any proposed alteration of the line. In several instances which might be named, the trunk-line roads have been justified in incurring very heavy expense in reducing distances and grades for the cheaper handling of greatly increased traffic.

CHAPTER XIX

LEVELING UNDER UNUSUAL CONDITIONS

390. The curvature of the earth. When very long sights are required to be taken with the level, the curvature of the earth must be considered.

A *level line* is parallel to a great circle of the earth and is therefore an arc of a circle or may be so considered.

A *horizontal line* is a straight line parallel to the plane of the horizon. Therefore, the line of sight, being a horizontal line, is tangent to the circle of a level line passing through the instrument.

To find the correction in elevation due to curvature of the earth for any distant station (Fig. 192).

Let A be the station of the instrument I and B the distant station observed.

Let $R_0 = CI$ = the radius of curvature of the earth or of the parallel arc ID . Let $L_0 = ID$ = the level distance between A and B . Then IE , perpendicular to CI , is the line of sight; BE is the reading of the rod; and $DE = E_0$ = the correction due to curvature.

By Table XLI, 24, $IE^2 = DE(DE + 2R_0)$; but, since DE is very small compared with $2R_0$, it may be omitted from the parenthesis, and, since $IE = ID = L_0$ very nearly, because the angle ACB is very small, we have $L_0^2 = 2R_0E_0$.

∴

$$E_0 = \frac{L_0^2}{2R_0} \quad (345)$$

E_0 is to be *added* to the apparent elevation of station B .

391. Refraction. In observing distant stations the line of sight passing through the atmosphere is refracted from the straight line IE (Fig. 192) and takes the form of a curve, which, for practical purposes, may be considered as the arc of a circle, concave downwards. Its radius, depending on

the conditions of the atmosphere, varies from $5\frac{1}{2}$ to $7\frac{1}{2}$ times the radius of curvature of the earth. $7R_0$ is considered a good average value.

Refraction causes the observed object to appear too high, whereas the curvature of the earth causes it to appear too low; the effects being contrary, the correction for curvature is reduced by the correction for refraction. If we let H_0 = the

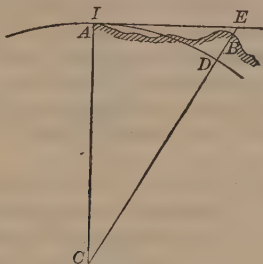


FIG. 192.

total correction for both curvature and refraction, to be *added* to the apparent elevation of the observed object, then,

$$H_0 = \frac{6}{7}E_0 = \frac{3L_0^2}{7R_0} \quad (346)$$

Table XVII is calculated by this formula, based on a mean value of $R_0 = 20,913,650$ ft.

392. The form of the earth is approximately an ellipsoid of revolution. Its meridian section at the mean level of the sea is an ellipse, the semiaxes of which are, according to Clarke,

At the equator $A = 6,378,206$ meters [6.8046985]

At the poles $B = 6,356,584$ meters [6.8032238]

According to the same authority,

$$1 \text{ meter} = 3.280869 \text{ ft [0.5159889]}$$

Therefore, the semiaxes expressed in feet are

$$A = 20,926,058 \text{ ft [7.3206874]}$$

$$B = 20,855,119 \text{ ft [7.3192127]}$$

Then, the radius of curvature of the meridian,

$$\text{At the equator, } \frac{B^2}{A} = R_0 = 20,784,422 \text{ ft [7.3177379]}$$

$$\text{At the poles, } \frac{A^2}{B} = R_0 = 20,997,240 \text{ ft [7.3221622]}$$

In latitude 40° the radius of curvature of the meridian is 20,871,900, and of a section at right angles to the meridian, 20,955,400; the mean value, or $R_0 = 20,913,650$ [7.320430], being adopted for general use. The error in the correction H_0 (equation 346) due to this assumption will usually be much less than that due to the assumed value of the radius of refraction.

393. Leveling by transit. When a transit has a level tube attached to the telescope, it may be used for finding the difference in elevation of points. If the instrument be in perfect adjustment, the line of sight will be horizontal when the bubble stands at the middle point of the tube, and the reading of the vertical circle will be zero. Should there be a small reading when the line of sight is horizontal, it is called the *index error*. When the line of sight is not horizontal, the angle which it makes with the plane of the horizon is called an angle of elevation, or of depression, according as the object on which the line of sight is directed is above or below the telescope. This angle is measured on the vertical circle, being the *difference* of the reading and the index error when both are on the same side of the zero mark and their *sum* when they are on opposite sides. When the distance to an observed object is known and its angle of elevation or depression is measured, we may calculate its vertical height above or below the telescope.

Let $\pm\alpha = \text{angle of } \begin{cases} \text{elevation} \\ \text{depression} \end{cases}$

$L = \text{the horizontal distance}$

$L' = \text{the distance parallel to line of sight}$

$h = \text{difference in elevation of object and instrument}$

Then for short distances,

$$h = L \tan \alpha = L' \sin \alpha \quad (347)$$

For long distances the curvature of the earth and refraction must be considered (Fig. 193).

Let I be the place of the instrument and F the object observed.

Let L_0 = the distance, measured on the chord of the level arc ID , passing through the instrument; and let ψ = the number of seconds in the arc ID ; hence, since for ordinary distances the chord and arc are sensibly equal:

$$\psi = \frac{L_0}{R_0} 206,264''.8 [5.314425]$$

or giving to R_0 its mean value, § 359, we have

$$\psi = L_0 \times 0.0098627 [7.993995]$$

or a fraction less than 1'' per 100 ft.

Let IF be the arc of the refracted ray, and, if it is assumed that its radius is $7R_0$, the arc will contain one-seventh the number of seconds of the arc IF .

IF' , tangent to IF , is the direction of the telescope; IF is the chord of the arc IF , and IE is the horizontal.

Let $\alpha = EIF'$ = observed angle of elevation. Then EIF = true angle of elevation = $EIF' - F'IF = \alpha - \frac{1}{2} \cdot \frac{1}{7} \psi = \alpha - 0.071\psi$.

The angle $EID = \frac{1}{2}\psi$. $\therefore DIF = \frac{1}{2}\psi + \alpha - 0.071\psi$; and $IDF = 90^\circ + \frac{1}{2}\psi$. $\therefore IFD = 90^\circ - (\psi + \alpha - 0.071\psi)$.

We now solve the triangle IFD for the side $DF = h$, and find

$$h = L_0 \frac{\sin (\frac{1}{2}\psi + \alpha - 0.071\psi)}{\cos (\psi + \alpha - 0.071\psi)} \quad (348)$$

For an observed angle of depression make α negative in the formula.

The coefficient 0.071 is called the coefficient of refraction, this being a fair average value, while its extreme range is from 0.067 to 0.100 under varying conditions of the atmosphere and values of the angle α .

When the difference in elevation of two or more distant objects is required, we obtain the elevation of each separately and subtract one elevation from another. The elevation of the observed object is given by $(H.I.) \pm h$.

394. *To find the height of instrument of a transit by an observation of the horizon* (Fig. 194).

Let I be the place of the instrument, and let α = observed angle of depression of the horizon.

Let F be the point where the refracted ray meets the level surface, and draw the chords IF and AF .

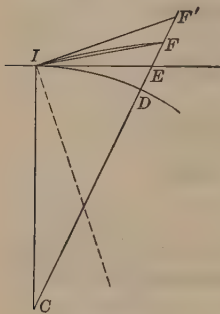


FIG. 193.

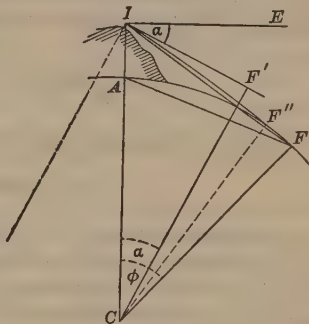


FIG. 194.

Let ψ = the angle ACF , let $h = AI$, and let k = the coefficient of refraction.

In the triangle IAF ,

$$IAF = 90^\circ + \frac{1}{2}\psi, \quad AFI = \frac{1}{2}\psi - k\psi, \quad AIF = 90^\circ - (\psi - k\psi)$$

Hence,

$$FIE = \psi - k\psi$$

but

$$FIE = \alpha + k\psi$$

$\therefore$

$$\psi = \frac{\alpha}{1-2k} \quad (349)$$

Let F'' be the tangent point of a right line drawn through I ; then $AI = CF'' \text{ ex sec } ACF''$, but $CF'' = R_0$, and, since ψ is always very small, $ACF'' = \frac{1}{2}(\psi + \alpha)$ very nearly $= \frac{1-k}{1-2k}\alpha$

$\therefore$

$$h = R_0 \text{ ex sec } \frac{1-k}{1-2k}\alpha \quad (350)$$

Giving to R_0 its mean value (§ 392) and assuming $k = \frac{1}{14}$, then

$$\log h = 7.320430 + \log \text{ex sec. } 1.0801\alpha \quad (351)$$

Otherwise: solve the triangle AIF since

$$AF = 2R_0 \sin \frac{1}{2}\psi = 2R_0 \sin \frac{\alpha}{2(1-2k)}$$

and

$$h = AF \frac{\sin (\frac{1}{2}\psi - k\psi)}{\cos (\psi - k\psi)}$$

$\therefore$

$$h = 2R_0 \sin \frac{\alpha}{2(1-2k)} \cdot \frac{\sin \frac{1}{2}\alpha}{\cos \frac{1-k}{1-2k}\alpha} \quad (352)$$

When $k = \frac{1}{14}$,

$$h = 2R_0 \sin \frac{7}{12}\alpha \cdot \frac{\sin \frac{1}{2}\alpha}{\cos \frac{1}{12}\alpha} \quad (353)$$

Example. The observed dip of the sea horizon is $24' = \alpha$. What is the height of the instrument above the sea?

By equation 351:

$$1.0801 \times \alpha \times 60 = 1555'' .34 \quad 3.191825$$

2

$$6.383650$$

$$\text{Table XXVI } (q-2l) \quad 9.070130$$

$$R_0 \quad 7.320430$$

$\therefore$

$$h = 594.58 \quad 2.774210$$

Methods of determining heights by distant observations cannot be relied on for more than approximate results, since they necessarily involve the uncertain element of refraction and usually a lack of precision in the vertical angle, the arc reading only to minutes in ordinary instruments. These methods, however, are useful where no great accuracy is required, as for a temporary purpose until levels can be taken in the regular way, or for interpolating between points of established elevation.

CHAPTER XX

ADJUSTMENT OF INSTRUMENTS

Every adjustment consists of two processes: first *the test*, and second *the correction*. Inasmuch as the amount of correction is made by estimation, the test must always be repeated until no further lack of adjustment is observable.

It is convenient to remember that all adjustment screws on an instrument are right-handed; that is, that they advance when turned clockwise.

The cross hairs of an instrument are supported on a ring called a reticle. The reticle is suspended in the center of the telescope tube by four adjusting screws in tension. Their heads are outside the tube, and, in pulling on the reticle, they press on the outside of the tube. The cross hairs are moved left and right or up and down by loosening one of a pair of opposite adjusting screws and tightening the other. Before beginning to move the cross hairs, the tension at right angles to the movement must be relieved by loosening one of the other screws. It is tightened again at the completion of the adjustment. If the tension is not relieved, all four screws will be pulling at a slight angle after the cross hairs have been moved. Vibration may then cause them to slip and thus ruin the adjustment.

All adjustment screws must be firm at the completion of each adjustment.

THE TRANSIT

395. The cross hair reticle must be oriented so that the vertical hair will lie in a plane perpendicular to the horizontal axis.

Test. Aim at some well-defined point and move the telescope slightly up and down. The vertical cross hair should remain on the point, if not . . .

Correction. Loosen two adjacent adjusting screws, and

slide all four screws around the telescope until the desired result is attained. Tighten the two screws that were loosened.

The bubbles of the plate levels should indicate zero when the vertical axis of the instrument is in line with the direction of gravity.

Test. Set the *A* vernier at zero with the upper motion. Turn the instrument with the lower motion until each plate level is parallel to a pair of opposite leveling screws. Level carefully. With the upper motion turn 180° . The bubbles should come to rest at the centers of their tubes; if either bubble fails to center . . .

Correction. Bring it *halfway* back to the center by turning the adjusting screw.

The line of collimation should be perpendicular to the horizontal axis.

Test: Clamp the limb, and by the tangent screws bring the intersection of the cross hairs to cover a well-defined point about on a level with the telescope: plunge the telescope to look in the opposite direction, and note any point about on a level with the telescope and about equidistant with the first point, which the intersection of the cross hairs now happens to cover. Now unclamp the limb, turn the telescope in azimuth, and repeat the above operation, using the same *first* point as before.

The *third* point obtained should be identical with the *second*; if not . . .

Correction: Move the vertical cross hair over *one fourth* of the apparent distance from the third to the second point, by turning the adjusting screws at the side of the telescope.

The horizontal axis should be perpendicular to the vertical axis.

Test: After completing these adjustments, level the instrument, clamp it, and bring the intersection of the cross hairs to cover some high point so that the telescope may be elevated to a large angle; depress the telescope, and note some point on the ground now covered by the intersection of the cross hairs.

Now unclamp the instrument, reverse the telescope, turn about 180° in azimuth, and bring the line of collimation on the point on the ground. Then elevate the telescope. The line

of collimation should cover the same high point as before; if not . . .

Correction. Raise or lower the adjustable end of the horizontal axis as required by turning the adjusting screws. The line of sight should usually be moved between *one-fourth* to *one-half* way back, the distance depending on the relation between the vertical angles used. The amount of motion required is best determined by repeated trials.

The intersection of the cross hairs should appear in the center of the field of view.

Test: Bring the cross hairs into focus and direct the telescope toward the sky, or hold a sheet of blank paper in front of it. If the intersection appears eccentric . . .

Correction: Turn the screws (by pairs) which support the end of the eyepiece until the desired result is obtained.

If there is a level on the telescope, its bubble should center when the line of collimation is level.

Drive two stakes equidistant from the instrument in exactly opposite directions, and, having perfected the previous adjustments, level the plate carefully, clamp the telescope in about a horizontal position, and observe a rod placed on each stake. Center the telescope bubble before each observation. Have the stakes driven by trial until the rod reads alike on both. The heads of the stakes are then on a level. Remove the instrument beyond one stake, and set it up in line with the two, level the plate, and elevate or depress the telescope to a position which will again give equal readings on the stakes. The line of collimation is now level.

Test: While in this position the bubble of the attached level should stand centered; if not . . .

Correction: Bring the bubble to the center by turning the nuts at one end of the tube, while the cross hair continues to give equal readings.

THE Y LEVEL

396. The line of collimation should coincide with the axis of the telescope.

Test: Clamp the spindle, open the clips, and bring the intersection of the cross hairs to cover a well-defined point by the tangent and leveling screws; revolve the telescope half over

in the Y's, so that the level tube is on top. The intersection of the cross hairs should still cover the point. If either hair has departed . . .

Correction: Bring it halfway back by means of the pair of adjusting screws at the extremities of the other hair.

The axis of the level tube should lie in a plane parallel to to or including the axis of the telescope.

Test: Center the bubble, and turn the telescope on its axis so as to bring the level tube out to one side. The bubble should remain centered. If it has departed . . .

Correction: Bring it back to the center by the adjusting screws at the side of the level tube.

The bubble of the attached level should center when the axis of the telescope is horizontal.

Test: Bring the telescope over one pair of leveling screws, clamp the spindle, open the clips, and bring the bubble to the center. Then gently remove the telescope from the Y's, and replace it end for end. If the Y's have not been disturbed, the bubble should return to the center. If it does not . . .

Correction: Bring the bubble halfway back by turning the nuts at one end of the tube.

The axis of the telescope should be at right angles to the spindle.

Test: Having completed these adjustments (and not before), fasten down the clips, unclamp the spindle, bring the bubble to the center over each pair of leveling screws in succession, and then swing the telescope end for end on the spindle. The bubble should settle at the center. If it does not . . .

Correction: Bring it halfway back by the large nuts at one end of the bar.

THE DUMPY LEVEL

397. The telescope of the dumpy level cannot be taken from the Y's; consequently, there are two adjustments only. These are:

The bubble should center when the axis of the spindle is vertical.

The *test* and *correction* are the same as for the plate-level adjustment of the transit.

The bubble of the attached level should center when the axis of the telescope is horizontal.

The *test* for this adjustment is the same as the corresponding one for the transit. The correct, however, is made by *changing the position of the reticle which carries the cross hairs*, the level vial remaining the same.

HIGHWAY CURVES

398. Highway practice. The practice among the various states of this country regarding horizontal alignment is not at all uniform. Several different methods are employed:

- (a) The arc definition is used.
- (b) An approximate arc method is employed.
- (c) The chord definition of degree of curve is used.
- (d) The curve may be designated by its radius, which is usually an even number of feet.
- (e) The length of tangent may be first selected.

For the different problems of widening, superelevation, forms of spirals, and the like the reader is referred to H. C. Ives' book entitled "Highway Curves," published by John Wiley & Sons.

399. Parts of a simple curve. The parts of a simple curve both for railroads and for highways are given in §§ 78, 85-93. See Fig. 195.

400. General formulas. Before numerical examples illustrating the different cases are given, certain formulas general to both railroad curves and highway curves are stated.

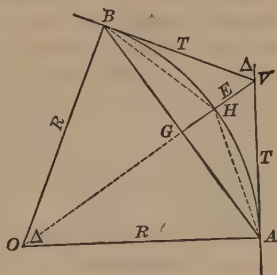


FIG. 195.

The equation numbers are the same as those used in Chapter V and are illustrated in part by Fig. 195.

$$T = R \tan \frac{1}{2}\Delta \quad (17)$$

$$C = 2R \sin \frac{1}{2}\Delta \quad (18)$$

$$M = R \text{ vers } \frac{1}{2}\Delta \quad (19)$$

$$E = R \text{ ex sec } \frac{1}{2}\Delta \quad (20)$$

Caution. In using these formulas, where R is given it should be substituted directly in the formula, but where D is given the value of R should be found from equation 44 deduced below.

CURVE TABLES

The description of the different tables is given at the end of Volume II, "Explanation of Tables," but, for the sake of completeness, certain facts are mentioned here.

All equations may be solved by logarithms, by natural functions by longhand, by use of the calculating machine, or in many cases by tables.

401. Value of the radius. For the arc definition of degree of curve, Table L is used; for the approximate arc method, the radius is found from equation 44. To avoid error, it is suggested that the value be checked with Table L, which will be nearly the same. For the chord definition, Table I is employed. Where the radius is chosen as an even number of feet, Table LI is used. Further suggestions in the application of these tables may be made in the explanation of the different methods of location.

402. Value of tangent. Table III may be used and will be found sufficiently exact for methods a , b , and c . In the arc definition *no correction* need be applied, but with the chord definition Table II gives the *necessary correction*. Where method d is the standard, equation 17 is the basis.

403. Values of C, M, and E. Tables IV, VI, and III will be found useful in the solution of equations 18–20. In the direct solution, care should be taken that the exact value of R be used.

Suggestion. The student is advised to make a table showing the minor differences in the values of the four curve elements resulting in the difference in definition of degree of curve, for three or four values such as 1, 3, 6, and 10° .

The different methods of curve location as stated in § 398 are now given.

404. (a) The arc definition. In this case, the *degree of curve* is designated as the *central angle subtended by an arc of 100 ft.* The length of curve is *measured along the arc* instead of by chords.

If the degree of curve is designated by D and expressed in degrees, we have the proportion:

$$D:360^\circ::100:2\pi R$$

$$R = \frac{100(360)}{2\pi D} = \frac{5729.58}{D} \quad (4A)$$

In other words, the *radius* varies *inversely* with the *degree of curve*. And

$$D = \frac{5729.58}{R} \quad (6A)$$

Caution. In using equations where R is given its value should be substituted directly in the formula, but where D is given R should be found from equation 4A.

405. Length of curve. As previously stated, a *highway curve* is measured on the *arc* of the curve.

Let R = the radius of a circular arc, of length L , and central angle a in degrees. As this arc is a proportional part of the whole circumference of the circle, we have

$$L:2\pi R::a^\circ:360^\circ$$

$$L = \frac{2\pi R a^\circ}{360^\circ} = 0.0174533a^\circ R$$

In other words, to find the length of curve, *multiply* the number of degrees in the central angle by the *radius* of the

curve and by the constant 0.0174533. When D is given,

$$L = \frac{100\Delta}{D} \quad (7)$$

With this equation it is to be noted that the length is also by *arc*.

Table XXA gives the lengths of circular arcs to radius = 1 for central angles up to 120° . The value of the arc to any radius may be found by multiplying the coefficient for the proper central angle by the given radius.

Table XXB gives the difference obtained by subtracting the length of the long chord from the length of the circular arc for arcs of unit radius having central angles of 0° to 92° . The exact value for any radius may be found by multiplying the value found in the table by the length of radius.

The length of the long chord is computed by subtracting the difference thus obtained from the length of arc. When the length of the chord computed by this means is compared to the length obtained by equation 18, the length of arc and the length of chord are both checked.

406. Example. *Given:* a simple curve connecting two tangents on a highway, with *degree of curve* given, in this case = $4^\circ 0'$. Also, $\Delta = 22^\circ 30'$; station of P.I. = $17+60.00$.

Then,

$$R = \frac{5729.58}{4} = 1432.395$$

$$T = R \tan \frac{1}{2}\Delta = 284.92$$

Find L by use of Table XXA, the coefficient for $22^\circ 30'$ being 0.39269909, and this multiplied by R of 1432.395 gives $L = 562.50$. Or, from equation 7, $L = 100(22.5^\circ) \div 4^\circ$.

If the long chord C is required, find in Table XXB the value for $\Delta = 22^\circ 30'$ which is 0.0025184. This multiplied by $R = 1432.395$ gives $A - C = 3.16$. Subtracting this from L (the arc length) = 562.50 gives $C = 558.89$. By equation 18,

$$C = 2R \sin \frac{\Delta}{2} = 558.89$$

which checks.

Then, P.C. = $17+60.00 - 284.92 = 14+75.08$, and P.T. = $14+75.08 + 562.50 = 20+37.58$.

The following table of deflections shows the method of continuous stations.

SIMPLE CURVE FOR HIGHWAY WHEN D IS GIVEN

Station	Point	Alignment	Deflection	Chord	Arc
+37.58	P.T.	.....	11° 15'	37.57	37.58
20	.....	$\Delta = 22^\circ 30'$	10° 29' 54''	99.98	100.00
19	.....	$D = 4^\circ 0'$	8° 29' 54''	99.98	100.00
18	.....	$R = 1432.395$	6° 29' 54''	99.98	100.00
17	.....	$T = 284.92$	4° 29' 54''	99.98	100.00
16	.....	$L = 562.50$	2° 29' 54''	99.98	100.00
15	.....	.....	29' 54''	24.92	24.92
14+75.08	P.C.	.....			

407. Field work. The description of the field work is given in § 418.

408. (b) The approximate arc method. An approximation is given for equation 4A and is

$$R = \frac{5730}{D} \quad (4B)$$

from which,

$$D = \frac{5730}{R} \quad (6B)$$

For those states using this method and these equations the tables of this book may be employed with sufficient exactness. The computations for the different parts of the curve and the field work are entirely similar to those in method *a*.

409. (c) The chord method. The computations and details for this method are fully explained in Chapter V. The degree of curve is the *central angle subtended by a chord of 100 ft.* Care should be taken that the proper values of R be used, and these are found in Table I. It is again mentioned that the length of curve is measured by chords. Where short chords are used, Table VII will prove of special service.

Note. Many states which use the chord definition for flatter curves, either use the arc definition for sharper curves, say, above 20° , or else select an even value for the radius. In such cases, the work follows that outlined in methods *a* or *d*.

410. (d) Where the radius is selected. A numerical example will illustrate this method:

Problem. Radius given, in this case = 400 ft. Also, given $\Delta = 29^\circ 40' 40''$, and P.I. 29+40.00.

From equation 17 or by use of Table III, $T = 106.00$.

$$\text{P.C.} = \text{P.I.} - T = 29+40.00 - 106.00 = 28+34.00$$

The length of curve is found by use of Table XXA.

$$\text{Coefficient for } 29^\circ 40' = 0.5177810$$

$$40'' = 0.0001939$$

$$\text{Coefficient for } 29^\circ 40' 40'' = 0.5179749$$

Then

$$L = 400 \times 0.5179749 = 207.19$$

$$\text{P.T.} = 28+34.00 + 207.19 = 30+41.19$$

411. Location of curve. The curve may be located by deflection angles in one of four ways.

Plan *a*. By keeping the stationing an even station or whole number of feet.

Plan *b*. By dividing the whole arc into an equal number of parts.

Plan *c*. By using a chord length of even number of feet for the first part of the curve and a final subchord to the P.T. of the curve.

Plan *d*. By taking a deflection angle of whole number of degrees and minutes for the first part of the curve and the remaining odd value for the subarc to the P.T.

In all four methods, all chords and arcs with their central angles must be given or found.

412. Plan a. Continuous stationing. Using the numerical example above, where $\Delta = 29^\circ 40' 40''$; $R = 400$ ft; $T = 106.00$; $L = 207.19$; P.C. 28+34.00; P.T. = 30+41.19.

The first point on the curve will be taken as station 28+50.00, and then 50-ft arcs to 30+00.00, with a subarc of 41.19 to the P.T.

Computations will first be made longhand or by calculating machine and then by use of tables.

The first short arc is 16.00 ft. The central angle for this arc with a 400-ft radius is found from the equation

$$\text{Angle} = \text{arc}/\text{radius} = 16/400 = 0.0400000$$

From Table XXA, the angle which will give this coefficient is $2^{\circ} 17' 30''$. The chord corresponding to the arc of 16.00 ft is found from a modification of equation 18, which is $c = 2R \sin \frac{1}{2}d = 2(400) \sin 1^{\circ} 08' 45'' = 16.00$.

Similarly, the central angles for the 50-ft arcs and the subarc of 41.19 at the end of the curve are $7^{\circ} 09' 43''$ and $5^{\circ} 54''$, respectively. The chords for arcs of 50 ft and 41.19 ft are 49.97 and 41.17.

By use of Table LI. The deflection for 1 ft of arc for a curve of 400-ft radius is $4.297'$. That for a 16-ft arc will be $16 \times 4.297' = 1^{\circ} 08' 45''$ which checks with the value found previously. The table does not give a 26-ft chord, but for a curve of 275-ft radius and a 25-ft chord it may be seen that chord and arc would be practically identical.

Equation for deflection angle. The central angle for a certain arc of radius R is given by the equation

$$d = \frac{360^{\circ} \text{ arc}}{2\pi R}$$

The deflection angle =

$$\frac{1}{2}d = \frac{360^{\circ}}{4\pi R} \text{ arc} = \frac{1718.87338 \text{ times the arc}}{R}$$

expressed in minutes. Table LI has been computed by means of this equation, which is one of the most useful equations in highway work.

Similarly the deflection angles for 50 and 41.19 are $3^{\circ} 34' 52''$ and $2^{\circ} 57'$ which check with previous quantities.

Recommendation. The method by use of Table LI is advocated since it appears to be the shortest one of all.

A check on the angle work will be the sum of the central angles which gives $2^{\circ} 17' 30'' + 3(7^{\circ} 09' 43'') + 5^{\circ} 54' = 29^{\circ} 40' 39''$ which checks Δ within 1 second.

For all practical purposes, the results might be rounded off somewhat, but they are carried to a point showing that as accurate results may be secured with short chords and radii as with long ones.

The following form of notes illustrates plan *a*:

FORM OF NOTES FOR EVEN FOOT STATIONS

Station	Point	Alignment	Deflection Angle	Chord	Arc
30+41.19	P.T.	$\Delta = 29^\circ 40' 40''$	$14^\circ 50' 20''$	41.17	41.19
30	.....	$R = 400.00$	$11^\circ 53' 18''$	49.97	50.00
29+50	.....	$T = 106.00$	$8^\circ 18' 27''$	49.97	50.00
29	.....	$L = 207.19$	$4^\circ 43' 36''$	49.97	50.00
+50	.....	P.I. = 29+40.00	$1^\circ 08' 45''$	16.00	16.00
28+34.00	P.C.	Regular arc = 50'			

413. Plan b. Again consider the numerical example given in *a*. Divide the total central angle into four equal parts which will subtend equal central angles. Then, the central angle of each arc will be one fourth of Δ or $7^\circ 25' 10''$. Each arc will be one fourth of L or 51.797. In the table this is rounded off to 51.80 with the last arc made to conform to L . The length of the uniform chord may be found from the equation

$$c = 2R \sin \frac{1}{2}d = 800 \sin 3^\circ 42' 35'' = 51.76$$

FORM OF NOTES FOR EVEN ARC LENGTHS

Station	Point	Alignment	Deflection Angle	Chord	Arc
30+41.19	P.T.	$\Delta = 29^\circ 40' 40''$	$14^\circ 50' 20''$	51.75	51.79
29+89.40	.....	$R = 400.00$	$11^\circ 07' 45''$	51.76	51.80
29+37.60	.....	$T = 106.00$	$7^\circ 25' 10''$	51.76	51.80
28+85.80	.....	$L = 207.19$	$3^\circ 42' 35''$	51.76	51.80
28+34.00	P.C.	P.I. = 29+40.00 4 Equal Arcs			

414. Plan c. As applied to the particular example given in *a* and *b* this plan would not be considered. If it were, 50 ft would be taken for the first three chords and the proper amount for the last one so as to close on the P.T. The length of arc for the chosen central angles could be found by use of Table XXA. The deflections can be found by equation $\sin \frac{1}{2}d = c/2R$ or by Table LI.

415. Plan d. A deflection angle of $4^\circ 0' 0''$ will be used for the first three chords and the remainder of $\frac{1}{2}\Delta$, namely,

$2^{\circ} 50' 20''$, for the final subchord. From Table XXA the arcs for twice these deflections may be found. The chords may be found from equation $c = 2R \sin \frac{1}{2}d$, or, once the arcs are found, the difference between arc and chord may be found. The form of notes is not given for this plan but might be compiled without difficulty.

416. Comparison of the different methods. Plan *a* has the advantage of even stationing in the result on plotting and in the calculation of earthwork. Plan *b* has the advantage of ease in computation. Plan *c* preserves a uniform chord in measurement with an odd chord at the end of the curve. Plan *d* has the advantage of ease in laying off deflections on the vernier.

The author prefers either plan *a* or plan *b*.

417. (e) Selection of the tangent distance. By equation 21, R may be found when T and D are given. This form of curve is illustrated in § 95 of Chapter V, and suggestions are there made for a final solution.

418. Field work. Suppose Δ has been measured either directly by prolonging the tangents to intersection or by the problem of V inaccessible. We can either assume D or find it by assuming one of the other curve elements.

Compute the value of T , and make up a list of deflections as previously explained. Then proceed as follows:

1. Lay off both tangents from point V or from points corresponding to p and q in Fig. 27, thus locating the P.C. and P.T.

2. Set up at the P.C., set vernier at zero, and sight at V . Unclamp the upper motion, and *if possible* sight at the P.T. The angle V —P.C.—P.T. should equal $\frac{1}{2}\Delta$. This will show that the tangents are *equal* in length but not necessarily of correct length.

3. From the list of deflections, lay out points on the curve using proper deflection angle and subchord or full chord as occasion demands.

Checks. The check on *computation* is that the deflection to the P.T. from the P.C. and sighting at V should equal $\frac{1}{2}\Delta$.

The check on *field work* is that the deflection angle V —P.C.—P.T. should equal $\frac{1}{2}\Delta$ and the measured length of the last chord should equal its computed length.

Setup on Curve. The method of procedure regarding measurement of distances is the same as where no setup on the curve is necessary. The angle $V-P.C.-P.T.$ cannot as a rule be checked in this case. The two methods of deflections are given in §§ 107 and 108.

419. Comparison between highway curve and railroad curve for same Δ and numerical value of D . For the problem given in § 406, on account of slightly different values of R due to definition of D , the value of T would be a little smaller. Consequently, the positions of the P.C. and P.T. would be a little nearer the P.I. in the highway curve than in the railroad curve, and the curve itself would assume a slightly different position on the ground.

420. The traverse method. Many of the special problems of simple and compound curves can be solved by treatment as closed traverses. Most books on surveying cover this work under the head, Missing Data.

In any closed survey, the algebraic sum of the latitudes is equal to zero, and likewise for the departures, north and east bearings being considered plus, and south and west bearings minus. Expressed in equation form:

$$l_1 \cos \alpha + l_2 \cos \beta + l_3 \cos \theta + \text{etc.} = 0$$

$$l_1 \sin \alpha + l_2 \sin \beta + l_3 \sin \theta + \text{etc.} = 0$$

In general, two methods of solution are given: (1) by the solution of equations, (2) by the transference of lines, thereby first forming a closed survey, with the smallest number of unknown quantities, and afterwards forming a triangle with sufficient known parts for a completion of the problem.

It is beyond the province of this book to go into this subject fully, but the student and reader, should they find it necessary, are referred to treatises on surveying.

COMPOUND AND REVERSED CURVES

421. The foregoing paragraphs show that all of the trigonometric formulas used for establishing the P.C. and the

P.T. of a simple curve are the same, no matter what definition of D is chosen. This principle is equally true for compound curves and reversed curves.

Specifically, the relationships among R , Δ , T , M , E , and C in simple curves; R_1 , R_2 , Δ_1 , Δ_2 , T_1 , T_2 , and C in compound curves; and r_1 , r_2 , Δ_1 , Δ_2 , VA , and VB in reversed curves are the same, no matter what definition of D is used. It is only after the P.I., P.C., and P.T., or their equivalents have been staked out that different formulas are required. Thereafter the definition of D is involved in determining the chords and deflection angles used in staking out the stations on the curve proper.

Of course, when R is computed from D , or vice versa, the formula that is used depends on the definition of D . This does not affect the trigonometric formulas in any way.

Example. Assume that a highway compound curve is to be staked out from the following data:

$$R_1 \text{ (the first radius) } = 500 \text{ ft; } R_2 = 1000 \text{ ft}$$

$$\Delta_1 = 32^\circ; \Delta = 44^\circ 12'; \text{ plus P.I. } = 22+39.23$$

By equations in § 150.

$$\Delta_2 = 44^\circ 12' - 32^\circ$$

$$\Delta_2 = 12^\circ 12'$$

$$T_1 = \frac{500 \text{ vers } 44^\circ 12' + (1000 - 500) \text{ vers } 12^\circ 12'}{\sin 44^\circ 12'}$$

$$T_1 = 219.23$$

$$T_2 = \frac{1000 \text{ vers } 44^\circ 12' - (1000 - 500) \text{ vers } 32^\circ}{\sin 44^\circ 12'}$$

$$T_2 = 297.08$$

$$\text{Plus P.C. } = 22+39.23 - 219.23 = 20+20.00.$$

It is possible to stake out the P.T. and the P.C. with these data alone. Observe that the definition of D has not been used.

Assume that the arc definition of D is desired.

By equation 6A,

$$D_1 = \frac{5729.58}{500} = 11.45916^\circ$$

$$D_2 = \frac{5729.58}{1000} = 5.72958^\circ$$

By equation 7,

$$L_1 = \frac{100 \times 32}{11.45916} = 279.25$$

$$L_2 = \frac{100 \times 12.2}{5.72958} = 212.93$$

Hence,

$$\begin{array}{rcl} \text{P.C.} & = & 20 + 20.00 \\ + L_1 & = & 2 \quad 79.25 \\ \hline \text{P.C.C.} & = & 22 + 99.25 \\ + L_2 & = & 2 \quad 12.93 \\ \hline \text{P.T.} & = & 25 + 12.18 \end{array}$$

From Table LI,

$$\frac{D_1}{2} = 2 \times 2^\circ 51.89' = 5^\circ 43.78'$$

$$\frac{d_1}{2} = 80 \times 3.438' = 275.040' = 4^\circ 35.04'$$

$$\frac{d_1'}{2} = 99.25 \times 3.438' = 341.122' = 5^\circ 41.22'$$

$$\frac{D_2}{2} = 2^\circ 51.89'$$

$$\frac{d_2}{2} = 0.75 \times 1.719' = 0^\circ 1.29'$$

$$\frac{d_2'}{2} = 12.18 \times 1.719' = 0^\circ 20.94'$$

The chords are interpolated from Table L

FIELD NOTES

Sta.	Chord	Deflec.	Curve Data	Dist.	Cal. Br.
⊙ +12.18 P.T.	12.18	6° 06.00'	R_1 500'		
25	99.96	5° 45.07'	R_2 1000'		
24	99.96	2° 53.18'	Δ 44° 12'		
23	0.75	0° 1.29'	Δ_1 32° 00'		
⊙ +99.25 P.C.C.	99.18	16° 00.00'	$\frac{1}{2}\Delta_1$ 16° 00'		
22	99.83	10° 18.82'	Δ_2 12° 12'		
21	79.95	4° 35.04'	$\frac{1}{2}\Delta_2$ 6° 06'		
⊙ +20.00 P.C.			T_1 219.23		
20			T_2 297.08		
19			L_1 279.25		
18			L_2 212.93		

It is clear that the only change in the computations are for curve points between the P.C. and the P.T.

A reversed curve is handled in the same way. The position of the P.C., P.R.C., and P.T. are computed according to the usual formulas. The chosen definition of D is then used for computing the deflections and chords for staking out the simple curves between these points.

SPIRALS

422. When the type and length of spiral has been selected according to the sharpness of the main curve and the velocity expected, the positions of the beginning and the end of the spirals are computed by the same formulas developed for railroad spirals.

Since the chords and the deflection angles are predetermined, they are always the same, no matter what may be the definition of D . The lengths of spiral chords (not long chords) are always so nearly the same as the lengths of the arcs they subtend that arcs and chords are always assumed to be exactly equal. Accordingly, the change in plus from the beginning to the end of a spiral is *always* equal to L , the length of spiral, which in turn is equal to the *sum of the lengths of the chords*. The plus of each spiral point is computed by adding the lengths of the chords involved. If it is necessary to mark the position of an exact station, the chord and the deflection angle necessary are found by straight-line interpolation between adjacent spiral points.

Example. The field notes are given for a spiral running from a tangent to a 6° curve.

$C = 30$, $n = 10$, $R = 300$, plus of point of spiral $23+41.11$

FIELD NOTES

Station		Chord	Deflec.
(10)	41.11 P.C.	30	$5^\circ 33' 27''$
(9)	11.11	11.11	$5^\circ 00' 05''$
	26	18.89	$4^\circ 47' 00''$
(8)	81.11	30	$4^\circ 26' 44''$
(7)	51.11	30	$3^\circ 53' 22''$
(6)	21.11	21.11	$3^\circ 20' 02''$
	25	8.89	$2^\circ 56' 34''$
(5)	91.11	30	$2^\circ 46' 41''$
(4)	61.11	30	$2^\circ 13' 20''$
(3)	31.11	30	$1^\circ 40' 00''$
(2)	1.11	1.11	$1^\circ 06' 40''$
	24	28.89	$1^\circ 05' 27''$
(1)	71.11	30	$0^\circ 33' 20''$
(0)	41.11 S.P. 23		





Volume of Triangular Prisms in Cu. Yds.

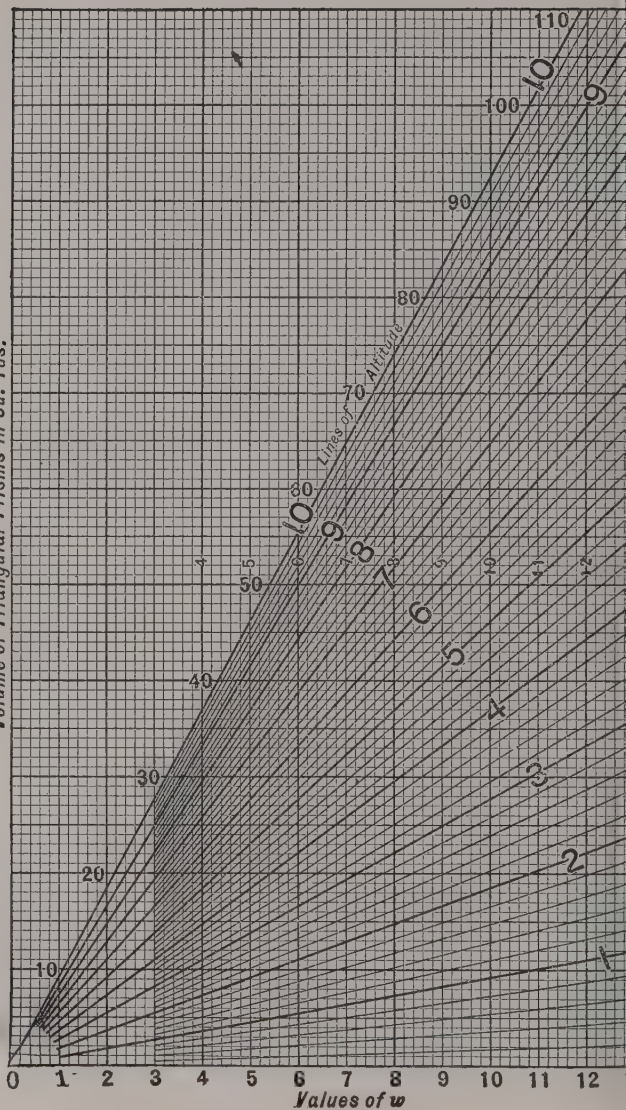
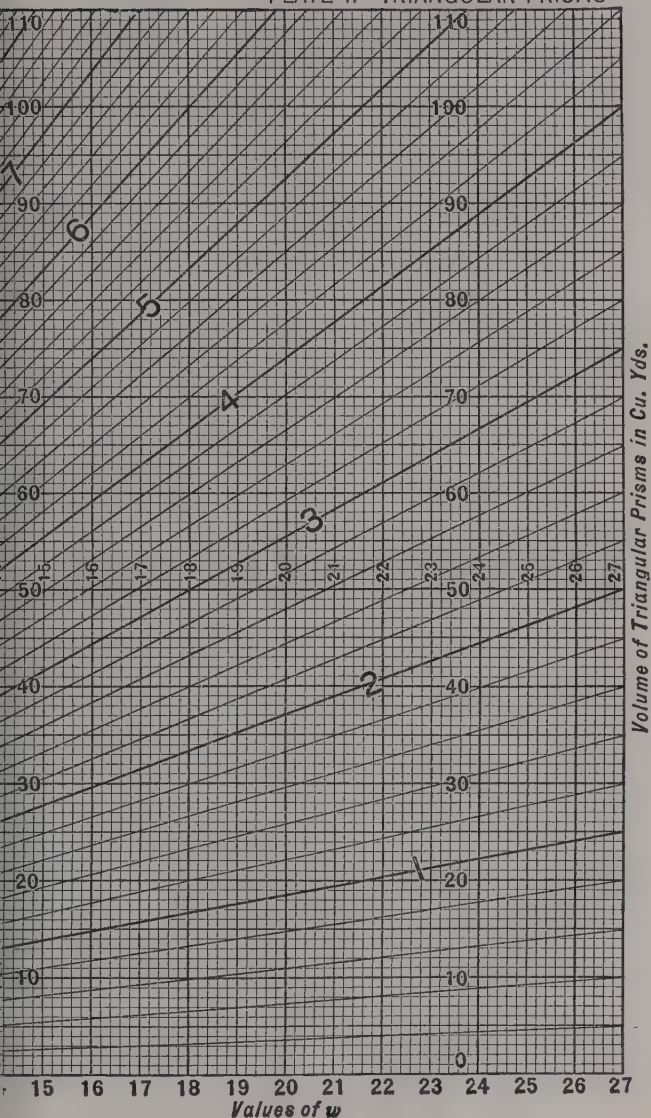
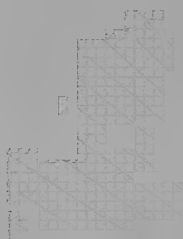


PLATE I. TRIANGULAR PRISMS



Volume of the ... in ...



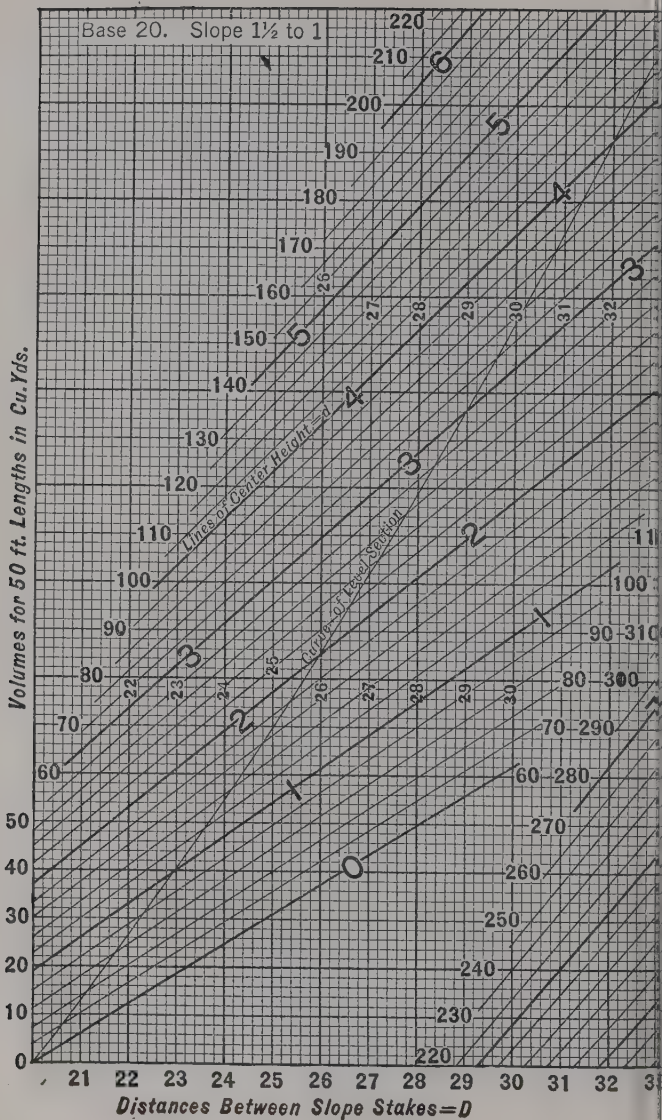
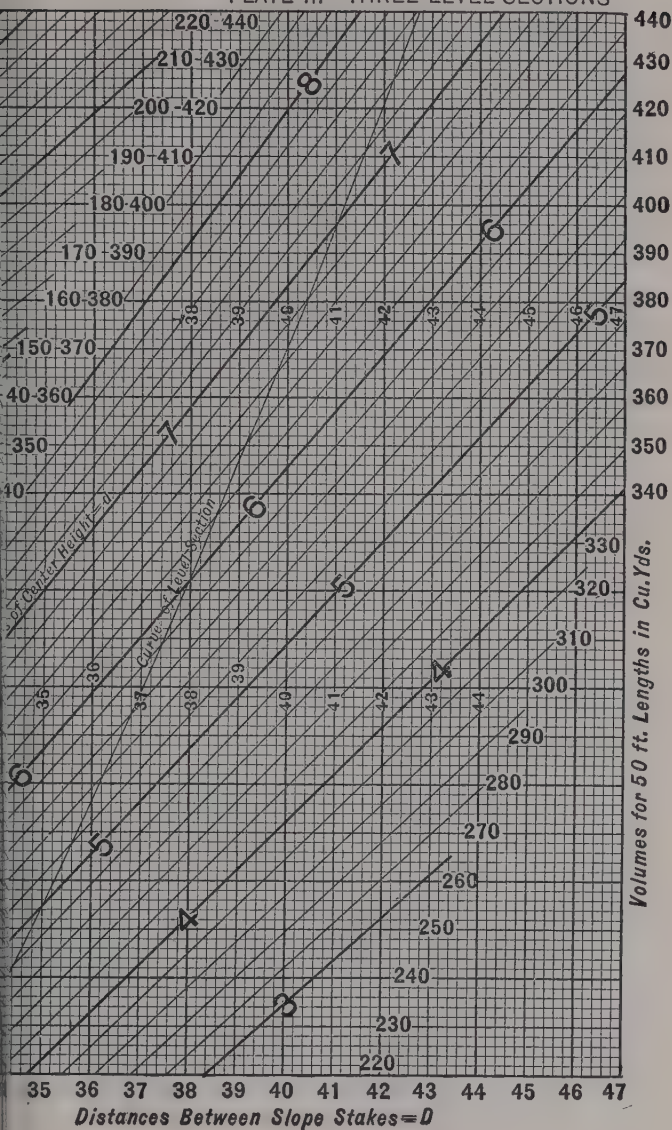
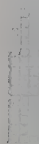


PLATE II. THREE LEVEL SECTIONS





Distances Between 21st & 22nd Streets

30 31 32 33 34



Volumes for 50 ft. Lengths in Cu. Yds.

Base 16. Slope $1\frac{1}{2}$ to 1

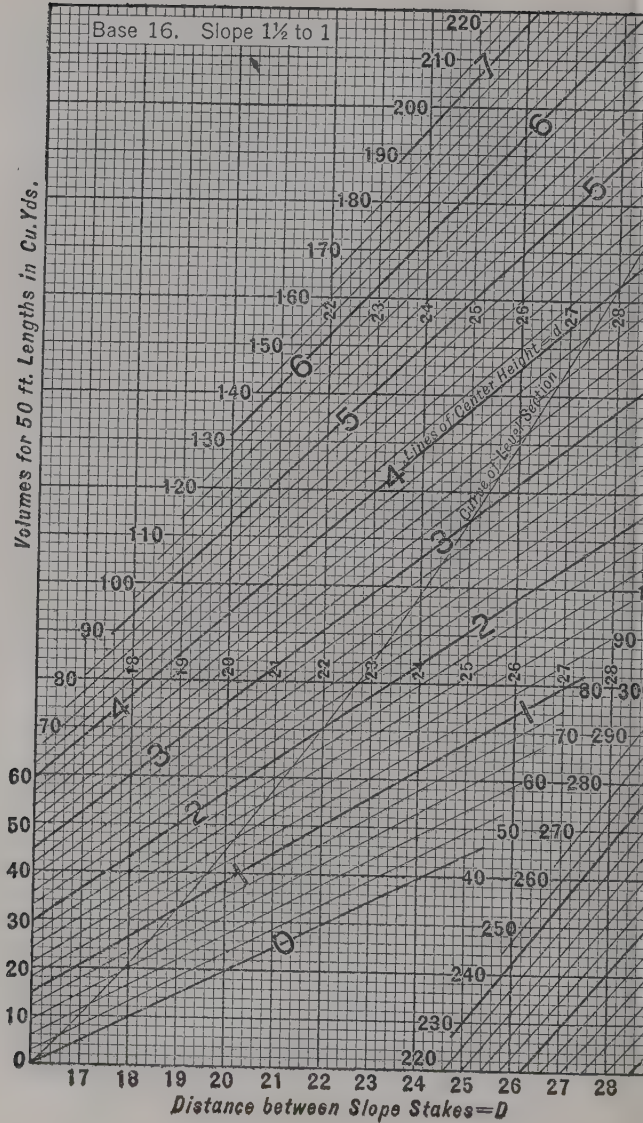
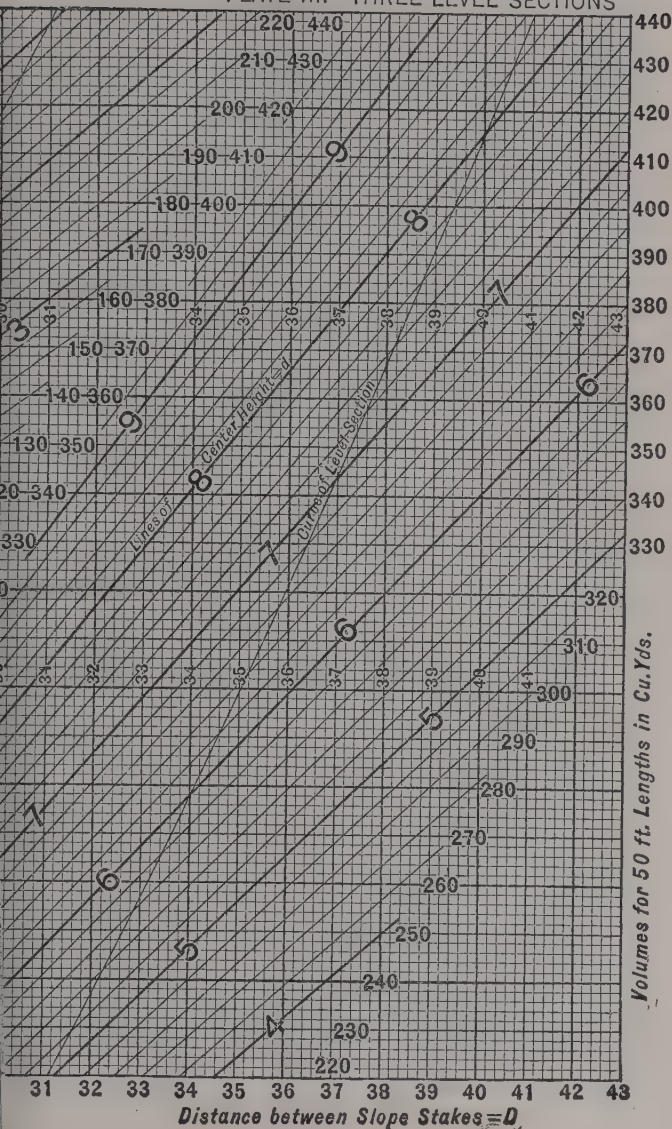
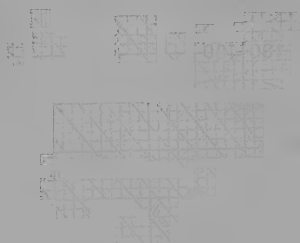


PLATE III. THREE LEVEL SECTIONS





Corrections in Cubic Yards

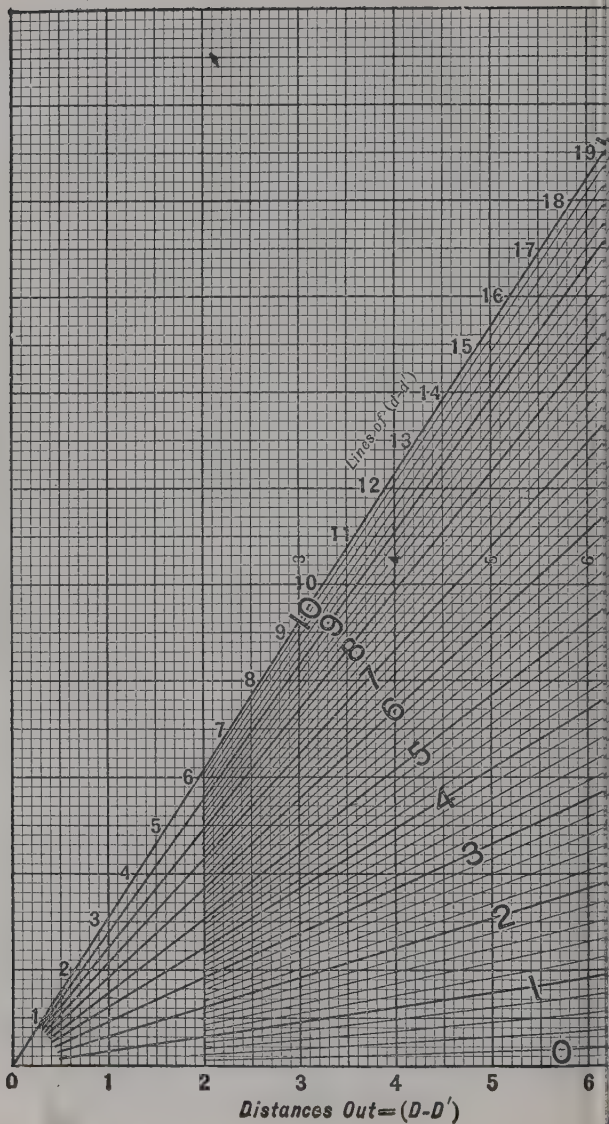
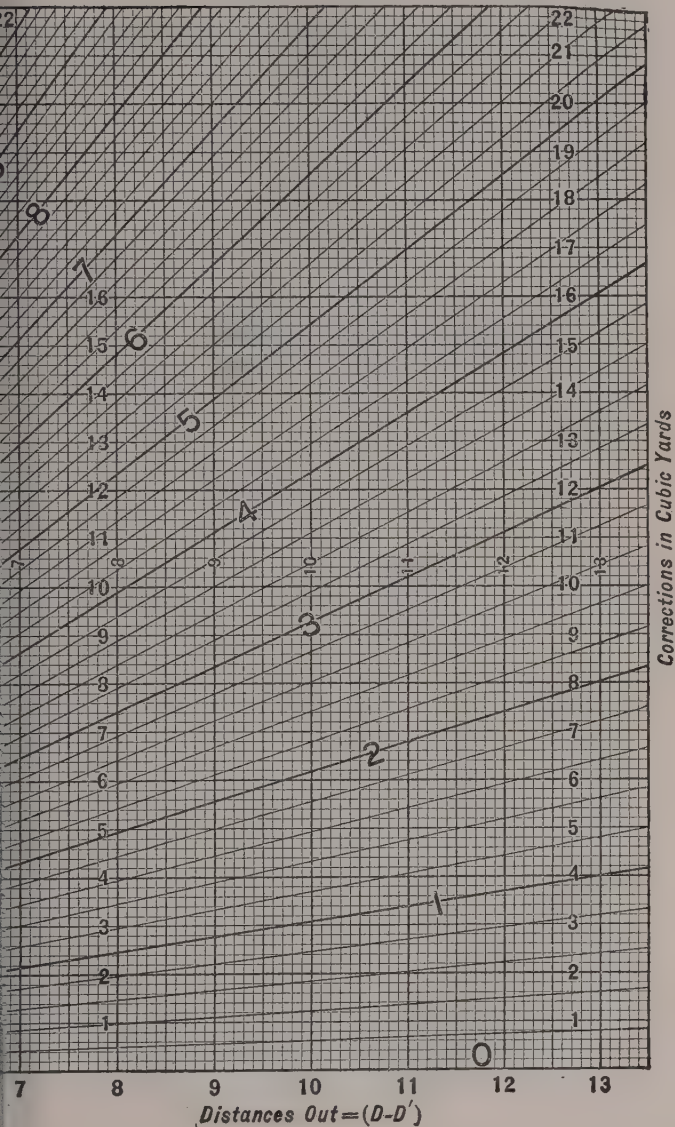


PLATE IV. PRISMOIDAL CORRECTIONS



FIELD ENGINEERING



FIELD ENGINEERING

A Handbook of the Theory and
Practice of Railway Surveying,
Location, and Construction

by

WILLIAM H. SEARLES, C.E.

Late Member American Society of Civil Engineers

and

HOWARD CHAPIN IVES, C.E.

Late Civil and Consulting Engineer

TWENTY-SECOND EDITION

by

PHILIP KISSAM, C.E.

Professor of Civil Engineering

Princeton University

Volume II. TABLES

NEW YORK · JOHN WILEY & SONS, INC.

LONDON · CHAPMAN & HALL, LIMITED

COPYRIGHT, 1880
BY JOHN WILEY & SONS
1880 COPYRIGHT RENEWED 1908

COPYRIGHT, 1915, 1919
BY WILLIAM H. SEARLES
AND
HOWARD CHAPIN IVES
1915 COPYRIGHT RENEWED 1942
1919 COPYRIGHT RENEWED 1946

COPYRIGHT, 1925, 1929
BY MARY D. SEARLES
AND
HOWARD CHAPIN IVES

COPYRIGHT, 1936
BY HELEN SEARLES MCLEOD
AND
HOWARD CHAPIN IVES

COPYRIGHT, 1949
BY JOHN WILEY & SONS, INC.

All Rights Reserved

*This book or any part thereof must not
be reproduced in any form without
the written permission of the publisher.*

TWENTY-SECOND EDITION
Second Printing, June, 1950

PRINTED IN THE UNITED STATES OF AMERICA

PREFACE TO THE TWENTY-SECOND EDITION

IN THIS edition, three tables have been enlarged and improved and a new table has been added.

Table VII now gives corrections to the nearest 0.01 ft for every 5 ft of chord length and for every degree of curvature up to 50°. It also gives factors which, when multiplied together, give these values to the nearest 0.001 ft.

Tables XXA and XXB were computed and arranged by Sol A. Bauer, a practicing civil engineer of Cleveland, Ohio. He has donated the tables as a contribution to the profession. They provide values to the eighth and seventh decimal places respectively and are the only tables of their kind, known to the author, that have been carried out to this precision. They replace old Table XX.

Table LI has been improved and enlarged in accordance with the more general use of this table.

P. K.

Princeton, N. J.
November 1948.

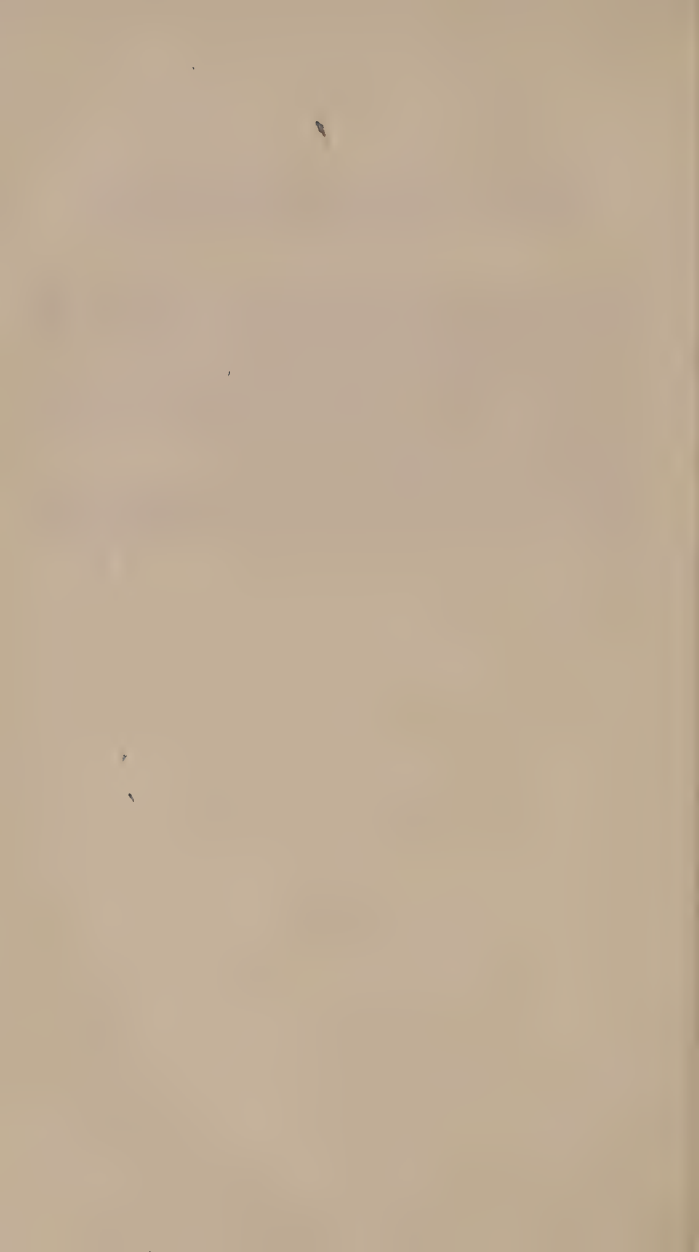
PREFACE TO THE TWENTY-FIRST EDITION

TABLES L, LI, and LII have been added to this edition. All are from the author's book entitled "Highway Curves." The inclusion of these tables will now enable all necessary highway-curve computations to be made with greater ease.

Thanks are due the American Railway Engineering Association, which furnished material for Tables XXIIA and XXIIB, replacing old tables of the same number.

In the previous edition, seven-place natural function tables replaced five-place ones. Also Table XLII, Trigonometric Formulas, was greatly extended.

H. C. I.



PREFACE TO THE NINETEENTH EDITION

BEGINNING with the seventeenth edition, the tables were published either separately or with the text.

In the present edition, old Table 7 is omitted and is replaced by a new Table 7 entitled "Corrections for Subchord Lengths," which did not previously have a separate number. The latter part of Table 9 is new and gives the "Elevation of the Outer Rail in Inches." Table 43, Formulas, and "Explanation of Tables" have been changed to conform to the revision of the text. The status of the other tables is as follows:

In the seventeenth edition sixteen new tables were added. These were: Tables Nos. 11, 12, 13, 19, 22A, 22B, and 31 to 40 inclusive. Table 18 replaced two tables in the previous edition. Tables 8, 9, 43 and 44 were either slightly changed or extended.

Tables 11, 12, 31 and 32 were computed anew. Tables 34 to 40 inclusive are from Searles' "Railroad Spiral," somewhat extended and rearranged.

In the eighteenth edition Tables 45 to 49 inclusive, on the American Railway Engineering Association Spiral, were added. Tables 45, 47 and 48 were computed in order to make the spiral easier of application.

The following from the preface to the first edition applies to other tables.

"Among the tables, Nos. 2, 3, 7, 26, 29 and 43 are original. The adoption of versed sines and external secants throughout the work, wherever these would simplify the formulas, rendered necessary the preparation of tables of these functions. The table of logarithmic versed sines and external secants has been computed from ten-place logarithmic tables of sines and tangents, so that the last decimal is to be relied on, and no pains have been spared to make the table thoroughly accurate.

"Tables Nos. 1, 4, 5, 6, 8, 9, 22 and 30 have been recalculated, enlarged, and some of them carried to more decimal places than similar tables heretofore published. The intention has been to give one more decimal than usual, so that in any combination of figures the result of calculation might be reliable to the last figure usually required.

"The tables which were compiled and rearranged are Nos. 15, 16, 17, 24, 25, 41, 42 and 44. The tables of log sines and tangents here given are the only six-place tables which give the differences correctly for seconds. The table of logarithms of numbers is accompanied by a complete table of proportional parts, which greatly facilitates interpolation for the fifth and sixth figures.

"In all the tables, whether new or old, scrupulous care has been taken to make the last figure correct, and the greatest diligence has been exercised by various checks and comparisons to eliminate every error. It is, therefore, hoped and believed that a very high degree of accuracy has been obtained, and that these tables will be found to stand second to none in this respect."

Acknowledgments are made to the American Railway Engineering Association to use material in Tables 9, 13, 22A, 22B, 33, 46 and 49; to W. & L. E. Gurley for permission to use the material in Table 19, which is from their manual.

All the tables herewith presented have been recently proof-read and are believed to be exceptionally accurate. The Publishers and Reviser will be grateful to readers who will call their attention to any errors discovered.

H. C. I.

December 1924.

TABLES

	PAGE
I. Radii, Offsets, and Ordinates	1
II. Corrections for Tangents and Externals	9
III. Tangents and Externals to a One-degree Curve	10
IV. Long Chords and Actual Arcs	14
V. Linear Deflections	19
VI. Middle Ordinates to Long Chords	20
VII. Corrections for Subchord Lengths	24
VIII. Middle Ordinates for Rails	26
IX. Difference in Elevation of Rails	27
X. Inches in Decimals of a Foot	28
XI. Metric Curves	29
XII. Acres for Strip 100 Ft. Wide	30
XIII. Velocity Heights	31
XIV. Grades and Grade Angles	32
XV. Barometric Heights, in Feet	34
XVI. Coefficient of Correction for Atmospheric Temperature	36
XVII. Correction for Earth's Curvature and Refraction	36
XVIII. Reduction of Stadia Readings	37
XIX. Mean Refractions in Declination	40
XXA. Lengths of Circular Arcs; Radius = 1	43
XXB. Arc Minus Chord when Radius = 1	44
XXI. Minutes in Decimals of a Degree	58
XXII. Frog Angles and Switches; Stub Switch	59
XXIIA. Split Switches; Frogs; Theoretical Leads	60
XXIIB. Split Switches; Practical Leads	62
XXIII. Squares, Cubes, Roots, and Reciprocals	64
XXIV. Logarithms of Numbers	81
XXV. Logarithmic Sines, Cosines, Tangents, and Cotangents	108
XXVI. Logarithmic Versed Sines and External Secants	153
XXVII. Natural Sines and Cosines	198
XXVIII. Natural Tangents and Cotangents	213
XXIX. Natural Versines and External Secants	228
XXIXA. Natural Secants and Cosecants	258
XXX. Cubic Yards per 100 Feet in Level Prismoids	274
XXXI. Triangular Prisms; Cubic Yards per 50 Feet	281
XXXII. Prismoidal Corrections; Cubic Yards per 100 Feet	291
XXXIII. Diagram for Length of Spirals	296
XXXIV. Elements of the Spiral of Chord-length 100	297
XXXV. Spiral Deflection Angles	298
XXXVI. Spiral Degrees of Curve and Coordinates, x, y	300
XXXVII. Functions of the Spiral Angle s	315
XXXVIII. Spiral Tangents, Long Chord, Coordinates p, q	316
XXXIX. Selected Curves with Proper Spirals and p, q	331

	PAGE
XL. Equal Length Curves with Spirals	336
XLI. Geometrical Propositions	338
XLII. Trigonometrical Formulas	340
XLIII. Formulas, Curves and Earthwork	350
XLIV. Useful Numbers and Formulas	358
XLV. Deflections for Ten-chord Spiral. Transit at <i>S</i>	360
XLVI. Coefficients for Deflections from Local Tangent at any Point	365
XLVII. Corrections in Minutes for Larger Deflections	366
XLVIII. Spiral Parts for Selected Curves	367
XLIX. Functions of the Ten-chord Spiral	375
L. Radii, Deflections, and Chords for Arc Definition of Degree of Curve	383
LI. Even Foot Radii. Deflections and Chords	395
LII. Coefficient <i>K</i> for Central Angles of Certain Curves . .	397
Explanation of Tables	399

TABLE I.—RADII, LOGARITHMS, OFFSETS, ETC.

Deg.	Radius.	Loga- rithm.	Tan. Off.	Mid. Ord.	Deg.	Radius.	Loga- rithm.	Tang. Off.	Mid. Ord.
D.	R.	log. R.	t.	m.	D.	R.	log. R.	t.	m.
0° 0'	Infinite	Infinite	.000	.000	1° 0'	5729.65	3.758128	.873	.218
1	343775.	5.536274	.015	.004	1	5635.72	.750950	.887	.222
2	171887.	5.235244	.029	.007	2	5544.83	.743888	.902	.225
3	114592.	5.059153	.044	.011	3	5456.82	.736939	.916	.229
4	85943.7	4.934214	.058	.015	4	5371.56	.730100	.931	.233
5	68754.9	.837304	.073	.018	5	5288.92	.723367	.945	.236
6	57295.8	.759123	.087	.022	6	5208.79	.716737	.960	.240
7	49110.7	.691176	.102	.025	7	5131.05	.710206	.974	.244
8	42971.8	.633184	.116	.029	8	5055.59	.703772	.989	.247
9	38197.2	.582031	.131	.033	9	4982.33	.697432	1.004	.251
10	34377.5	4.536274	.145	.036	10	4911.15	3.691183	1.018	.255
11	31252.3	4.494881	.160	.040	11	4841.98	3.685023	1.033	.258
12	28647.8	.457093	.175	.044	12	4774.74	.678949	1.047	.262
13	26444.2	.422331	.189	.047	13	4709.33	.672959	1.062	.265
14	24555.4	.390146	.204	.051	14	4645.69	.667051	1.076	.269
15	22918.3	.360183	.218	.055	15	4583.75	.661221	1.091	.273
16	21485.9	.332154	.233	.058	16	4523.44	.655469	1.105	.276
17	20222.1	.305825	.247	.062	17	4464.70	.649792	1.120	.280
18	19098.6	.281002	.262	.065	18	4407.46	.644189	1.134	.284
19	18093.4	.257521	.276	.069	19	4351.67	.638656	1.149	.287
20	17188.8	4.235244	.291	.073	20	4297.28	3.633194	1.164	.291
21	16370.2	4.214055	.305	.076	21	4244.23	3.627799	1.178	.295
22	15626.1	.193852	.320	.080	22	4192.47	.622470	1.193	.298
23	14946.7	.174547	.335	.084	23	4141.96	.617206	1.207	.302
24	14324.0	.156064	.349	.087	24	4092.66	.612005	1.222	.305
25	13751.0	.138335	.364	.091	25	4044.51	.606866	1.236	.309
26	13222.1	.121302	.378	.095	26	3997.49	.601787	1.251	.313
27	12732.4	.104911	.393	.098	27	3951.54	.596766	1.265	.316
28	12277.7	.089117	.407	.102	28	3906.64	.591803	1.280	.320
29	11854.3	.073877	.422	.105	29	3862.74	.586896	1.294	.324
30	11459.2	4.059154	.436	.109	30	3819.83	3.582044	1.309	.327
31	11089.6	4.044914	.451	.113	31	3777.85	3.577245	1.324	.331
32	10743.0	.031125	.465	.116	32	3736.79	.572499	1.338	.335
33	10417.5	.017762	.480	.120	33	3696.61	.567804	1.353	.338
34	10111.1	4.004797	.495	.124	34	3657.29	.563160	1.367	.342
35	9822.18	3.992208	.509	.127	35	3618.80	.558564	1.382	.345
36	9549.34	.979973	.524	.131	36	3581.10	.554017	1.396	.349
37	9291.25	.968074	.538	.135	37	3544.19	.549517	1.411	.353
38	9046.75	.956493	.553	.138	38	3508.02	.545063	1.425	.356
39	8814.78	.945212	.567	.142	39	3472.59	.540654	1.440	.360
40	8594.42	3.934216	.582	.145	40	3437.87	3.536289	1.454	.364
41	8384.80	3.923493	.596	.149	41	3403.83	3.531968	1.469	.367
42	8185.16	.913027	.611	.153	42	3370.46	.527690	1.483	.371
43	7994.81	.902808	.625	.156	43	3337.74	.523453	1.498	.375
44	7813.11	.892824	.640	.160	44	3305.65	.519257	1.513	.378
45	7639.49	.883085	.654	.164	45	3274.17	.515101	1.527	.382
46	7473.42	.873519	.669	.167	46	3243.29	.510985	1.542	.385
47	7314.41	.864179	.684	.171	47	3212.98	.506908	1.556	.389
48	7162.03	.855036	.698	.174	48	3183.23	.502868	1.571	.393
49	7015.87	.846082	.713	.178	49	3154.03	.498866	1.585	.396
50	6875.55	3.837308	.727	.182	50	3125.36	3.494900	1.600	.400
51	6740.74	3.828708	.742	.185	51	3097.20	3.490970	1.614	.404
52	6611.12	.820275	.756	.189	52	3069.55	.487075	1.629	.407
53	6486.38	.812002	.771	.193	53	3042.39	.483215	1.643	.411
54	6366.26	.803885	.785	.196	54	3015.71	.479389	1.658	.414
55	6250.51	.795916	.800	.200	55	2989.48	.475596	1.673	.418
56	6138.90	.788091	.814	.204	56	2963.72	.471836	1.687	.422
57	6031.20	.780404	.829	.207	57	2938.39	.468109	1.702	.425
58	5927.22	.772851	.844	.211	58	2913.49	.464418	1.716	.429
59	5826.76	.765427	.858	.215	59	2889.01	.460749	1.731	.433
60	5729.65	3.758128	.873	.218	60	2864.93	3.457115	1.745	.436

2 TABLE I.—RADII, LOGARITHMS, OFFSETS, ETC.

Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.
2° 0'	2864.93	3.457115	1.745	.436	3° 0'	1910.08	3.281051	2.618	.654
1	2841.26	.453511	1.760	.440	1	1899.53	.278646	2.632	.658
2	2817.97	.449937	1.774	.444	2	1889.09	.276253	2.647	.662
3	2795.06	.446392	1.789	.447	3	1878.77	.273874	2.661	.665
4	2772.53	.442876	1.803	.451	4	1868.56	.271508	2.676	.669
5	2750.35	.439388	1.818	.454	5	1858.47	.269155	2.690	.673
6	2728.52	.435928	1.832	.458	6	1848.48	.266814	2.705	.676
7	2707.04	.432495	1.847	.462	7	1838.59	.264486	2.719	.680
8	2685.89	.429089	1.862	.465	8	1828.82	.262170	2.734	.684
9	2665.08	.425710	1.876	.469	9	1819.14	.259867	2.749	.687
10	2644.58	3.422356	1.891	.473	10	1809.57	3.257576	2.763	.691
11	2624.39	3.419029	1.905	.476	11	1800.10	3.255296	2.778	.694
12	2604.51	.415727	1.920	.480	12	1790.73	.253029	2.792	.698
13	2584.93	.412449	1.934	.484	13	1781.45	.250774	2.807	.702
14	2565.65	.409197	1.949	.487	14	1772.27	.248530	2.821	.705
15	2546.64	.405968	1.963	.491	15	1763.18	.246297	2.836	.709
16	2527.92	.402763	1.978	.494	16	1754.19	.244077	2.850	.713
17	2509.47	.399582	1.992	.498	17	1745.29	.241867	2.865	.716
18	2491.29	.396424	2.007	.502	18	1736.48	.239669	2.879	.720
19	2473.37	.393289	2.022	.505	19	1727.75	.237481	2.894	.723
20	2455.70	3.390176	2.036	.509	20	1719.12	3.235305	2.908	.727
21	2438.29	3.387085	2.051	.513	21	1710.57	3.233140	2.923	.731
22	2421.12	.384016	2.065	.516	22	1702.10	.230985	2.938	.734
23	2404.19	.380969	2.080	.520	23	1693.72	.228841	2.952	.738
24	2387.50	.377943	2.094	.524	24	1685.42	.226707	2.967	.742
25	2371.04	.374938	2.109	.527	25	1677.20	.224584	2.981	.745
26	2354.80	.371954	2.123	.531	26	1669.06	.222472	2.996	.749
27	2338.78	.368990	2.138	.534	27	1661.00	.220369	3.010	.753
28	2322.98	.366046	2.152	.538	28	1653.01	.218277	3.025	.756
29	2307.39	.363122	2.167	.542	29	1645.11	.216195	3.039	.760
30	2292.01	3.360217	2.181	.545	30	1637.28	3.214122	3.054	.763
31	2276.84	3.357332	2.196	.549	31	1629.52	3.212060	3.068	.767
32	2261.86	.354466	2.211	.553	32	1621.84	.210007	3.083	.771
33	2247.08	.351618	2.225	.556	33	1614.22	.207964	3.097	.774
34	2232.49	.348789	2.240	.560	34	1606.68	.205930	3.112	.778
35	2218.09	.345979	2.254	.564	35	1599.21	.203906	3.127	.782
36	2203.87	.343187	2.269	.567	36	1591.81	.201892	3.141	.785
37	2189.84	.340412	2.283	.571	37	1584.48	.199886	3.156	.789
38	2175.98	.337655	2.298	.574	38	1577.21	.197890	3.170	.793
39	2162.30	.334916	2.312	.578	39	1570.01	.195903	3.185	.796
40	2148.79	3.332193	2.327	.582	40	1562.88	3.193925	3.199	.800
41	2135.44	3.329488	2.341	.585	41	1555.81	3.191956	3.214	.803
42	2122.26	.326799	2.356	.589	42	1548.80	.189996	3.228	.807
43	2109.24	.324127	2.371	.593	43	1541.86	.188045	3.243	.811
44	2096.39	.321471	2.385	.596	44	1534.98	.186103	3.257	.814
45	2083.68	.318832	2.400	.600	45	1528.16	.184169	3.272	.818
46	2071.13	.316208	2.414	.604	46	1521.40	.182244	3.286	.822
47	2058.73	.313600	2.429	.607	47	1514.70	.180327	3.301	.825
48	2046.48	.311008	2.443	.611	48	1508.06	.178419	3.316	.829
49	2034.37	.308431	2.458	.614	49	1501.48	.176519	3.330	.832
50	2022.41	3.305869	2.472	.618	50	1494.95	3.174627	3.345	.836
51	2010.59	3.303323	2.487	.622	51	1488.48	3.172744	3.359	.840
52	1998.90	.300791	2.501	.625	52	1483.07	.170865	3.374	.843
53	1987.35	.298274	2.516	.629	53	1475.71	.169001	3.388	.847
54	1975.93	.295771	2.530	.633	54	1469.41	.167142	3.403	.851
55	1964.64	.293283	2.545	.636	55	1463.16	.165291	3.417	.854
56	1953.48	.290809	2.560	.640	56	1456.96	.163447	3.432	.858
57	1942.44	.288349	2.574	.644	57	1450.81	.161612	3.446	.862
58	1931.53	.285902	2.589	.647	58	1444.72	.159784	3.461	.865
59	1920.75	.283470	2.603	.651	59	1438.68	.157963	3.475	.869
60	1910.08	3.281051	2.618	.654	60	1432.69	3.156151	3.490	.872

TABLE I.—RADII, LOGARITHMS, OFFSETS, ETC.

Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.
1° 0'	1432.69	3.156151	3.490	.872	5° 0'	1146.28	3.059290	4.362	1.091
1	1426.74	.154346	3.505	.876	1	1142.47	.057846	4.376	1.094
2	1420.85	.152548	3.519	.880	2	1138.69	.056407	4.391	1.098
3	1415.01	.150758	3.534	.883	3	1134.94	.054972	4.405	1.102
4	1409.21	.148975	3.548	.887	4	1131.21	.053542	4.420	1.105
5	1403.46	.147200	3.563	.891	5	1127.50	.052116	4.435	1.109
6	1397.76	.145431	3.577	.894	6	1123.82	.050696	4.449	1.112
7	1392.10	.143670	3.592	.898	7	1120.16	.049280	4.464	1.116
8	1386.49	.141916	3.606	.902	8	1116.52	.047868	4.478	1.120
9	1380.92	.140170	3.621	.905	9	1112.91	.046462	4.493	1.123
10	1375.40	3.138430	3.635	.909	10	1109.33	3.045059	4.507	1.127
11	1369.92	3.136697	3.650	.912	11	1105.76	3.043662	4.522	1.131
12	1364.49	.134971	3.664	.916	12	1102.22	.042268	4.536	1.134
13	1359.10	.133251	3.679	.920	13	1098.70	.040880	4.551	1.138
14	1353.75	.131539	3.693	.923	14	1095.20	.039495	4.565	1.142
15	1348.45	.129833	3.708	.927	15	1091.73	.038115	4.580	1.146
16	1343.18	.128134	3.723	.931	16	1088.28	.036740	4.594	1.149
17	1337.96	.126442	3.737	.934	17	1084.85	.035368	4.609	1.153
18	1332.77	.124756	3.752	.938	18	1081.44	.034002	4.623	1.157
19	1327.63	.123077	3.766	.942	19	1078.05	.032639	4.638	1.160
20	1322.53	3.121404	3.781	.945	20	1074.68	3.031281	4.653	1.164
21	1317.46	3.119738	3.795	.949	21	1071.34	3.029927	4.667	1.168
22	1312.43	.118078	3.810	.952	22	1068.01	.028577	4.682	1.171
23	1307.45	.116424	3.824	.956	23	1064.71	.027231	4.696	1.175
24	1302.50	.114777	3.839	.960	24	1061.43	.025890	4.711	1.179
25	1297.58	.113136	3.853	.963	25	1058.16	.024552	4.725	1.182
26	1292.71	.111501	3.868	.967	26	1054.92	.023219	4.740	1.186
27	1287.87	.109872	3.882	.971	27	1051.70	.021890	4.754	1.190
28	1283.07	.108249	3.897	.974	28	1048.49	.020565	4.769	1.193
29	1278.30	.106632	3.911	.978	29	1045.31	.019244	4.783	1.197
30	1273.57	3.105022	3.926	.982	30	1042.14	3.017927	4.798	1.200
31	1268.87	3.103417	3.941	.985	31	1039.00	3.016614	4.812	1.204
32	1264.21	.101818	3.955	.989	32	1035.87	.015305	4.827	1.208
33	1259.58	.100225	3.970	.993	33	1032.76	.013999	4.841	1.211
34	1254.98	.098638	3.984	.996	34	1029.67	.012698	4.856	1.215
35	1250.42	.097057	3.999	1.000	35	1026.60	.011401	4.870	1.218
36	1245.89	.095481	4.013	1.003	36	1023.55	.010107	4.885	1.222
37	1241.40	.093912	4.028	1.007	37	1020.51	.008818	4.900	1.226
38	1236.94	.092347	4.042	1.011	38	1017.49	.007532	4.914	1.229
39	1232.51	.090789	4.057	1.014	39	1014.50	.006250	4.929	1.233
40	1228.11	3.089236	4.071	1.018	40	1011.51	3.004972	4.943	1.237
41	1223.74	3.087689	4.086	1.022	41	1008.55	3.003698	4.958	1.240
42	1219.40	.086147	4.100	1.025	42	1005.60	.002427	4.972	1.244
43	1215.09	.084610	4.115	1.029	43	1002.67	3.001160	4.987	1.247
44	1210.82	.083079	4.129	1.032	44	999.762	2.999897	5.001	1.251
45	1206.57	.081553	4.144	1.036	45	996.867	.998637	5.016	1.255
46	1202.36	.080033	4.159	1.040	46	993.988	.997381	5.030	1.258
47	1198.17	.078518	4.173	1.043	47	991.126	.996129	5.045	1.262
48	1194.01	.077008	4.188	1.047	48	988.280	.994880	5.059	1.266
49	1189.88	.075504	4.202	1.051	49	985.451	.993635	5.074	1.269
50	1185.78	3.074005	4.217	1.054	50	982.638	2.992398	5.088	1.273
51	1181.71	3.072511	4.231	1.058	51	979.840	2.991155	5.103	1.277
52	1177.66	.071022	4.246	1.062	52	977.060	.989921	5.117	1.280
53	1173.65	.069538	4.260	1.065	53	974.294	.988690	5.132	1.284
54	1169.66	.068059	4.275	1.069	54	971.544	.987463	5.146	1.288
55	1165.70	.066585	4.289	1.073	55	968.810	.986238	5.161	1.291
56	1161.76	.065116	4.304	1.076	56	966.091	.985018	5.175	1.295
57	1157.85	.063653	4.318	1.080	57	963.387	.983801	5.190	1.298
58	1153.97	.062194	4.333	1.083	58	960.698	.982587	5.205	1.302
59	1150.11	.060740	4.347	1.088	59	958.025	.981377	5.219	1.306
60	1146.28	3.059290	4.362	1.091	60	955.366	2.980170	5.234	1.309

4 TABLE I.—RADII, LOGARITHMS, OFFSETS, ETC.

Deg.	Radius.	Loga- rithm.	Tang. Off.	Mid. Ord.	Deg.	Radius.	Loga- rithm.	Tang. Off.	Mid. Ord.
D.	R.	log. R.	t.	m.	D.	R.	log. R.	t.	m.
6° 0'	955.366	2.980170	5.234	1.309	7° 0'	819.020	2.913295	6.105	1.528
1	952.722	.978966	5.248	1.313	1	817.077	.912263	6.119	1.531
2	950.093	.977766	5.263	1.317	2	815.144	.911234	6.134	1.535
3	947.478	.976569	5.277	1.320	3	813.219	.910208	6.148	1.539
4	944.877	.975375	5.292	1.324	4	811.303	.909183	6.163	1.543
5	942.291	.974185	5.306	1.327	5	809.397	.908162	6.177	1.546
6	939.719	.972998	5.321	1.331	6	807.499	.907142	6.192	1.550
7	937.161	.971814	5.335	1.335	7	805.611	.906125	6.206	1.553
8	934.616	.970633	5.350	1.338	8	803.731	.905111	6.221	1.557
9	932.086	.969456	5.364	1.342	9	801.860	.904098	6.236	1.561
10	929.569	.968282	5.379	1.346	10	799.997	2.903089	6.250	1.564
11	927.066	2.967111	5.393	1.349	11	798.144	2.902081	6.265	1.568
12	924.576	.965943	5.408	1.353	12	796.299	.901076	6.279	1.572
13	922.100	.964778	5.422	1.356	13	794.462	.900073	6.294	1.575
14	919.637	.963616	5.437	1.360	14	792.634	.899073	6.308	1.579
15	917.187	.962458	5.451	1.364	15	790.814	.898074	6.323	1.582
16	914.750	.961303	5.466	1.368	16	789.003	.897078	6.337	1.586
17	912.326	.960150	5.480	1.371	17	787.200	.896085	6.352	1.590
18	909.915	.959001	5.495	1.375	18	785.405	.895094	6.366	1.593
19	907.517	.957855	5.510	1.378	19	783.618	.894105	6.381	1.597
20	905.131	2.956711	5.524	1.382	20	781.840	2.893118	6.395	1.600
21	902.758	2.955571	5.539	1.386	21	780.069	2.892133	6.410	1.604
22	900.397	.954434	5.553	1.389	22	778.307	.891151	6.424	1.608
23	898.048	.953300	5.568	1.393	23	776.552	.890171	6.439	1.611
24	895.712	.952168	5.582	1.397	24	774.806	.889193	6.453	1.615
25	893.388	.951040	5.597	1.400	25	773.067	.888217	6.468	1.619
26	891.076	.949915	5.611	1.404	26	771.336	.887244	6.482	1.623
27	888.776	.948792	5.626	1.407	27	769.613	.886272	6.497	1.626
28	886.488	.947673	5.640	1.411	28	767.897	.885303	6.511	1.630
29	884.211	.946556	5.655	1.415	29	766.190	.884336	6.526	1.633
30	881.946	2.945442	5.669	1.418	30	764.489	2.883371	6.540	1.637
31	879.693	2.944331	5.684	1.422	31	762.797	2.882409	6.555	1.641
32	877.451	.943223	5.698	1.426	32	761.112	.881448	6.569	1.644
33	875.221	.942118	5.713	1.429	33	759.434	.880490	6.584	1.648
34	873.002	.941015	5.727	1.433	34	757.764	.879534	6.598	1.651
35	870.795	.939916	5.742	1.437	35	756.101	.878580	6.613	1.655
36	868.598	.938819	5.756	1.440	36	754.445	.877627	6.627	1.659
37	866.412	.937725	5.771	1.444	37	752.796	.876678	6.642	1.662
38	864.238	.936633	5.785	1.447	38	751.155	.875730	6.656	1.666
39	862.075	.935545	5.800	1.451	39	749.521	.874784	6.671	1.670
40	859.922	2.934459	5.814	1.455	40	747.894	2.873840	6.685	1.673
41	857.780	2.933376	5.829	1.458	41	746.274	2.872898	6.700	1.677
42	855.648	.932295	5.844	1.462	42	744.661	.871959	6.714	1.680
43	853.527	.931218	5.858	1.466	43	743.055	.871021	6.729	1.684
44	851.417	.930142	5.873	1.469	44	741.456	.870086	6.743	1.688
45	849.317	.929070	5.887	1.473	45	739.864	.869152	6.758	1.691
46	847.228	.928000	5.902	1.476	46	738.279	.868221	6.773	1.695
47	845.148	.926933	5.916	1.480	47	736.701	.867291	6.787	1.699
48	843.080	.925869	5.931	1.484	48	735.129	.866363	6.802	1.702
49	841.021	.924807	5.945	1.487	49	733.564	.865438	6.816	1.706
50	838.972	2.923747	5.960	1.491	50	732.005	2.864514	6.831	1.710
51	836.938	2.922691	5.974	1.495	51	730.454	2.863593	6.845	1.713
52	834.904	.921637	5.989	1.498	52	728.909	.862673	6.860	1.717
53	832.885	.920585	6.003	1.502	53	727.370	.861755	6.874	1.720
54	830.876	.919536	6.018	1.505	54	725.838	.860840	6.889	1.724
55	828.876	.918489	6.032	1.510	55	724.312	.859926	6.903	1.728
56	826.886	.917446	6.047	1.513	56	722.793	.859014	6.918	1.731
57	824.905	.916404	6.061	1.517	57	721.280	.858104	6.932	1.735
58	822.934	.915365	6.076	1.520	58	719.774	.857196	6.947	1.739
59	820.973	.914329	6.090	1.524	59	718.273	.856290	6.961	1.742
60	819.020	2.913295	6.105	1.528	60	716.779	2.855385	6.976	1.746

Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.
8° 0'	716.779	2.855385	6.976	1.746	9° 0'	637.275	2.804327	7.846	1.965
1	715.291	.854483	6.990	1.749	1	636.099	.803525	7.860	1.968
2	713.810	.853583	7.005	1.753	2	634.928	.802724	7.875	1.972
3	712.335	.852684	7.019	1.756	3	633.761	.801926	7.889	1.975
4	710.865	.851787	7.034	1.760	4	632.599	.801128	7.904	1.979
5	709.402	.850892	7.048	1.764	5	631.440	.800332	7.918	1.983
6	707.945	.849999	7.063	1.768	6	630.286	.799538	7.933	1.987
7	706.493	.849108	7.077	1.771	7	629.136	.798745	7.947	1.990
8	705.048	.848219	7.092	1.775	8	627.991	.797953	7.962	1.994
9	703.609	.847331	7.106	1.778	9	626.849	.797163	7.976	1.998
10	702.175	2.846445	7.121	1.782	10	625.712	2.796374	7.991	2.001
11	700.748	2.845562	7.135	1.786	11	624.579	2.795587	8.005	2.005
12	699.326	.844679	7.150	1.790	12	623.450	.794801	8.020	2.008
13	697.910	.843799	7.164	1.793	13	622.325	.794017	8.034	2.012
14	696.499	.842921	7.179	1.797	14	621.203	.793234	8.049	2.016
15	695.095	.842044	7.193	1.801	15	620.087	.792453	8.063	2.019
16	693.696	.841169	7.208	1.804	16	618.974	.791673	8.078	2.023
17	692.302	.840296	7.222	1.807	17	617.865	.790894	8.092	2.026
18	690.914	.839424	7.237	1.811	18	616.760	.790117	8.107	2.030
19	689.532	.838555	7.251	1.815	19	615.660	.789341	8.121	2.034
20	688.156	2.837687	7.266	1.819	20	614.563	2.788566	8.136	2.037
21	686.785	2.836821	7.280	1.822	21	613.470	2.787793	8.150	2.041
22	685.419	.835956	7.295	1.826	22	612.380	.787021	8.165	2.045
23	684.059	.835093	7.309	1.829	23	611.295	.786251	8.179	2.048
24	682.704	.834232	7.324	1.833	24	610.214	.785482	8.194	2.052
25	681.354	.833373	7.338	1.837	25	609.136	.784714	8.208	2.056
26	680.010	.832515	7.353	1.840	26	608.062	.783948	8.223	2.060
27	678.671	.831660	7.367	1.844	27	606.992	.783183	8.237	2.063
28	677.338	.830805	7.382	1.848	28	605.926	.782420	8.252	2.066
29	676.008	.829953	7.396	1.851	29	604.864	.781657	8.266	2.070
30	674.686	2.829102	7.411	1.855	30	603.805	2.780897	8.281	2.074
31	673.369	2.828253	7.425	1.858	31	602.750	2.780137	8.295	2.077
32	672.056	.827405	7.440	1.862	32	601.698	.779379	8.310	2.081
33	670.748	.826560	7.454	1.866	33	600.651	.778622	8.324	2.084
34	669.446	.825715	7.469	1.869	34	599.607	.777867	8.339	2.088
35	668.148	.824873	7.483	1.873	35	598.567	.777112	8.353	2.092
36	666.856	.824032	7.498	1.877	36	597.530	.776360	8.368	2.096
37	665.568	.823193	7.512	1.880	37	596.497	.775608	8.382	2.099
38	664.286	.822355	7.527	1.884	38	595.467	.774858	8.397	2.103
39	663.008	.821519	7.541	1.888	39	594.441	.774109	8.411	2.106
40	661.736	2.820685	7.556	1.892	40	593.419	2.773361	8.426	2.110
41	660.468	2.819852	7.570	1.895	41	592.400	2.772615	8.440	2.113
42	659.205	.819021	7.585	1.899	42	591.384	.771870	8.455	2.117
43	657.947	.818191	7.599	1.903	43	590.372	.771126	8.469	2.121
44	656.694	.817363	7.614	1.906	44	589.364	.770383	8.484	2.125
45	655.446	.816537	7.628	1.910	45	588.359	.769642	8.498	2.128
46	654.202	.815712	7.643	1.914	46	587.357	.768902	8.513	2.132
47	652.963	.814889	7.657	1.918	47	586.359	.768164	8.527	2.135
48	651.729	.814067	7.672	1.921	48	585.364	.767426	8.542	2.139
49	650.499	.813247	7.686	1.924	49	584.373	.766690	8.556	2.142
50	649.274	2.812428	7.701	1.928	50	583.385	2.765955	8.571	2.145
51	648.054	2.811611	7.715	1.932	51	582.400	2.765221	8.585	2.150
52	646.838	.810796	7.730	1.935	52	581.419	.764489	8.600	2.154
53	645.627	.809982	7.744	1.939	53	580.441	.763758	8.614	2.158
54	644.420	.809169	7.759	1.943	54	579.466	.763028	8.629	2.161
55	643.218	.808358	7.773	1.946	55	578.494	.762299	8.643	2.165
56	642.021	.807549	7.788	1.950	56	577.526	.761572	8.658	2.168
57	640.828	.806741	7.802	1.953	57	576.561	.760845	8.672	2.172
58	639.639	.805935	7.817	1.957	58	575.599	.760120	8.687	2.175
59	638.455	.805130	7.831	1.961	59	574.641	.759397	8.701	2.179
60	637.275	2.804327	7.846	1.965	60	573.686	2.758674	8.716	2.183

Deg.	Radius.	Loga- rithm.	Tang. Off.	Mid. Ord.	Deg.	Radius.	Loga- rithm.	Tang. Off.	Mid. Ord.
D.	R.	log. R.	t.	m.	D.	R.	log. R.	t.	m.
10° 0'	578.686	2.758674	8.716	2.183	12° 0'	478.339	2.679735	10.453	2.620
2	571.784	.757232	8.745	2.190	2	477.018	.678535	10.482	2.628
4	569.896	.755796	8.774	2.198	4	475.705	.677338	10.511	2.635
6	568.020	.754364	8.803	2.205	6	474.400	.676145	10.540	2.642
8	566.156	.752937	8.831	2.212	8	473.102	.674954	10.569	2.650
10	564.305	.751514	8.860	2.219	10	471.810	.673767	10.597	2.657
12	562.466	.750096	8.889	2.227	12	470.526	.672584	10.626	2.664
14	560.638	.748683	8.918	2.234	14	469.249	.671403	10.655	2.671
16	558.823	.747274	8.947	2.241	16	467.978	.670226	10.684	2.679
18	557.019	2.745870	8.976	2.249	18	466.715	2.669052	10.713	2.686
20	555.227	2.744471	9.005	2.256	20	465.459	2.667881	10.742	2.693
22	553.447	.743076	9.034	2.263	22	464.209	.666713	10.771	2.701
24	551.678	.741686	9.063	2.270	24	462.966	.665549	10.800	2.708
26	549.920	.740300	9.092	2.278	26	461.729	.664387	10.829	2.715
28	548.174	.738918	9.121	2.285	28	460.500	.663229	10.858	2.722
30	546.438	.737541	9.150	2.293	30	459.276	.662074	10.887	2.730
32	544.714	.736169	9.179	2.300	32	458.060	.660922	10.916	2.737
34	543.001	.734800	9.208	2.307	34	456.850	.659773	10.945	2.744
36	541.298	.733436	9.237	2.314	36	455.646	.658628	10.973	2.752
38	539.606	2.732077	9.266	2.321	38	454.449	2.657485	11.002	2.759
40	537.924	2.730721	9.295	2.329	40	453.259	2.656345	11.031	2.766
42	536.253	.729370	9.324	2.336	42	452.073	.655208	11.060	2.774
44	534.593	.728023	9.353	2.343	44	450.894	.654075	11.089	2.781
46	532.943	.726681	9.382	2.351	46	449.722	.652944	11.118	2.788
48	531.303	.725342	9.411	2.358	48	448.556	.651816	11.147	2.795
50	529.673	.724008	9.440	2.365	50	447.395	.650691	11.176	2.803
52	528.053	.722677	9.469	2.372	52	446.241	.649570	11.205	2.810
54	526.443	.721351	9.498	2.380	54	445.093	.648451	11.234	2.817
56	524.843	.720029	9.527	2.387	56	443.951	.647335	11.263	2.825
58	523.252	2.718711	9.556	2.394	58	442.814	2.646221	11.291	2.832
11° 0'	521.671	2.717397	9.585	2.402	13° 0'	441.684	2.645111	11.320	2.839
2	520.100	.716087	9.614	2.409	2	440.559	.644004	11.349	2.846
4	518.539	.714781	9.642	2.416	4	439.440	.642899	11.378	2.854
6	516.986	.713479	9.671	2.423	6	438.326	.641798	11.407	2.861
8	515.443	.712181	9.700	2.431	8	437.219	.640699	11.436	2.868
10	513.909	.710887	9.729	2.438	10	436.117	.639603	11.465	2.876
12	512.385	.709596	9.758	2.445	12	435.020	.638510	11.494	2.883
14	510.869	.708310	9.787	2.453	14	433.929	.637419	11.523	2.890
16	509.363	.707027	9.816	2.460	16	432.844	.636331	11.552	2.898
18	507.865	2.705748	9.845	2.467	18	431.764	2.635246	11.580	2.905
20	506.376	2.704473	9.874	2.475	20	430.690	2.634164	11.609	2.912
22	504.896	.703202	9.903	2.482	22	429.620	.633085	11.638	2.919
24	503.425	.701934	9.932	2.489	24	428.557	.632008	11.667	2.927
26	501.962	.700671	9.961	2.496	26	427.498	.630934	11.696	2.934
28	500.507	.699410	9.990	2.504	28	426.445	.629863	11.725	2.941
30	499.061	.698154	10.019	2.511	30	425.396	.628794	11.754	2.949
32	497.624	.696901	10.048	2.518	32	424.354	.627728	11.783	2.956
34	496.195	.695652	10.077	2.526	34	423.316	.626665	11.812	2.963
36	494.774	.694407	10.106	2.533	36	422.283	.625604	11.840	2.971
38	493.361	2.693165	10.135	2.540	38	421.256	2.624546	11.869	2.978
40	491.956	2.691926	10.164	2.547	40	420.233	2.623490	11.898	2.985
42	490.559	.690692	10.192	2.555	42	419.215	.622437	11.927	2.992
44	489.171	.689460	10.221	2.562	44	418.203	.621387	11.956	3.000
46	487.790	.688233	10.250	2.569	46	417.195	.620339	11.985	3.007
48	486.417	.687008	10.279	2.577	48	416.192	.619294	12.014	3.014
50	485.051	.685788	10.308	2.584	50	415.194	.618251	12.043	3.022
52	483.694	.684570	10.337	2.591	52	414.201	.617211	12.071	3.029
54	482.344	.683357	10.366	2.598	54	413.212	.616173	12.100	3.036
56	481.001	.682146	10.395	2.606	56	412.229	.615138	12.129	3.044
58	479.666	.680939	10.424	2.613	58	411.250	.614106	12.158	3.051
60	478.339	2.679735	10.453	2.620	60	410.275	2.613075	12.187	3.058

Deg. D.	Radius. R.	Loga- rithm. log. R.	Tan. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Loga- rithm. log. R.	Tan. Off. t.	Mid. Ord. m.
14° 0'	410.275	2.613075	12.187	3.058	16° 0'	359.265	2.555415	13.917	3.496
2	409.306	.612048	12.216	3.065	2	358.523	.554517	13.946	3.504
4	408.341	.611023	12.245	3.073	4	357.784	.553621	13.975	3.511
6	407.380	.610000	12.274	3.080	6	357.048	.552727	14.004	3.518
8	406.424	.608980	12.302	3.087	8	356.315	.551834	14.033	3.526
10	405.473	.607962	12.331	3.095	10	355.585	.550944	14.061	3.533
12	404.526	.606946	12.360	3.102	12	354.859	.550055	14.090	3.540
14	403.583	.605933	12.389	3.109	14	354.135	.549169	14.119	3.547
16	402.645	.604923	12.418	3.117	16	353.414	.548284	14.148	3.555
18	401.712	.603914	12.447	3.124	18	352.696	.547401	14.177	3.562
20	400.782	2.602908	12.476	3.131	20	351.981	2.546519	14.205	3.569
22	399.857	.601905	12.504	3.138	22	351.269	.545640	14.234	3.577
24	398.937	.600904	12.533	3.146	24	350.560	.544762	14.263	3.584
26	398.020	.599905	12.562	3.153	26	349.854	.543887	14.292	3.591
28	397.108	.598908	12.591	3.160	28	349.150	.543013	14.320	3.599
30	396.200	.597914	12.620	3.168	30	348.450	.542140	14.349	3.606
32	395.296	.596922	12.649	3.175	32	347.752	.541270	14.378	3.613
34	394.396	.595933	12.678	3.182	34	347.057	.540401	14.407	3.621
36	393.501	.594945	12.706	3.190	36	346.365	.539535	14.436	3.628
38	392.609	.593960	12.735	3.197	38	345.676	.538670	14.464	3.635
40	391.722	2.592978	12.764	3.204	40	344.990	2.537806	14.493	3.643
42	390.838	.591997	12.793	3.211	42	344.306	.536945	14.522	3.650
44	389.959	.591019	12.822	3.219	44	343.625	.536085	14.551	3.657
46	389.084	.590043	12.851	3.226	46	342.947	.535227	14.580	3.664
48	388.212	.589069	12.880	3.233	48	342.271	.534370	14.608	3.672
50	387.345	.588097	12.908	3.241	50	341.598	.533516	14.637	3.679
52	386.481	.587128	12.937	3.248	52	340.928	.532663	14.666	3.686
54	385.621	.586161	12.966	3.255	54	340.260	.531811	14.695	3.694
56	384.765	.585196	12.995	3.263	56	339.595	.530962	14.723	3.701
58	383.913	.584233	13.024	3.270	58	338.933	.530114	14.752	3.708
15° 0	383.065	2.583272	13.053	3.277	17° 0	338.273	2.529268	14.781	3.716
2	382.220	.582314	13.081	3.284	2	337.616	.528424	14.810	3.723
4	381.380	.581358	13.110	3.292	4	336.962	.527581	14.838	3.730
6	380.543	.580403	13.139	3.299	6	336.310	.526740	14.867	3.738
8	379.709	.579451	13.168	3.306	8	335.660	.525900	14.896	3.745
10	378.880	.578501	13.197	3.314	10	335.013	.525062	14.925	3.752
12	378.054	.577553	13.226	3.321	12	334.369	.524226	14.954	3.760
14	377.231	.576608	13.254	3.328	14	333.727	.523392	14.982	3.767
16	376.412	.575664	13.283	3.336	16	333.088	.522559	15.011	3.774
18	375.597	.574722	13.312	3.343	18	332.451	.521728	15.040	3.781
20	374.786	2.573783	13.341	3.350	20	331.816	2.520898	15.069	3.789
22	373.977	.572845	13.370	3.358	22	331.184	.520070	15.097	3.796
24	373.173	.571910	13.399	3.365	24	330.555	.519244	15.126	3.803
26	372.372	.570977	13.427	3.372	26	329.928	.518419	15.155	3.811
28	371.574	.570045	13.456	3.379	28	329.303	.517596	15.184	3.818
30	370.780	.569116	13.485	3.387	30	328.689	.516774	15.212	3.825
32	369.989	.568189	13.514	3.394	32	328.061	.515954	15.241	3.833
34	369.202	.567264	13.543	3.401	34	327.443	.515136	15.270	3.840
36	368.418	.566340	13.572	3.409	36	326.828	.514319	15.299	3.847
38	367.637	.565419	13.600	3.416	38	326.215	.513504	15.327	3.855
40	366.859	2.564500	13.629	3.423	40	325.604	2.512690	15.356	3.862
42	366.085	.563582	13.658	3.431	42	324.996	.511878	15.385	3.869
44	365.315	.562667	13.687	3.438	44	324.390	.511067	15.414	3.877
46	364.547	.561754	13.716	3.445	46	323.786	.510258	15.442	3.884
48	363.783	.560843	13.744	3.452	48	323.184	.509445	15.471	3.891
50	363.022	.559933	13.773	3.460	50	322.585	.508645	15.500	3.899
52	362.264	.559026	13.802	3.467	52	321.989	.507840	15.529	3.906
54	361.510	.558120	13.831	3.474	54	321.394	.507037	15.557	3.915
56	360.758	.557216	13.860	3.482	56	320.801	.506236	15.586	3.920
58	360.010	.556315	13.889	3.489	58	320.211	.505436	15.615	3.928
60	359.265	2.555415	13.917	3.496	60	319.623	2.504638	15.643	3.935

Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.
18° 0'	319.623	2.504638	15.643	3.935	20° 0'	287.939	2.459300	17.365	4.374
2	319.037	.503841	15.612	3.942	10	285.583	.455733	17.508	4.411
4	318.453	.503045	15.701	3.950	20	283.267	.452195	17.651	4.448
6	317.871	.502251	15.730	3.957	30	280.988	.448688	17.794	4.484
8	317.292	.501459	15.758	3.964	40	278.746	.445209	17.937	4.521
10	316.715	.500668	15.787	3.972	50	276.541	.441759	18.081	4.558
12	316.139	.499879	15.816	3.979	21° 0'	274.370	2.438337	18.224	4.594
14	315.566	.499091	15.845	3.986	10	272.234	.434943	18.367	4.631
16	314.993	.498304	15.873	3.994	20	270.132	.431576	18.509	4.668
18	314.426	.497519	15.902	4.001	30	268.062	.428235	18.652	4.704
20	313.860	2.496736	15.931	4.008	40	266.024	.424921	18.795	4.741
22	313.295	.495953	15.959	4.016	50	264.018	.421633	18.938	4.778
24	312.732	.495173	15.988	4.023	22° 0'	262.042	2.418371	19.081	4.814
26	312.172	.494393	16.017	4.030	10	260.098	.415134	19.224	4.851
28	311.613	.493616	16.046	4.038	20	258.180	.411922	19.366	4.888
30	311.056	.492839	16.074	4.045	30	256.292	.408734	19.509	4.925
32	310.502	.492064	16.103	4.052	40	254.431	.405571	19.652	4.961
34	309.949	.491291	16.132	4.060	50	252.599	.402431	19.794	4.998
36	309.399	.490518	16.160	4.067	23° 0'	250.793	2.399315	19.937	5.035
38	308.850	.489748	16.189	4.074	10	249.013	.396222	20.079	5.071
40	308.303	2.488978	16.218	4.081	20	247.258	.393151	20.222	5.108
42	307.759	.488210	16.246	4.089	30	245.529	.390103	20.364	5.145
44	307.216	.487444	16.275	4.096	40	243.825	.387077	20.507	5.182
46	306.675	.486679	16.304	4.103	50	242.144	.384074	20.649	5.218
48	306.136	.485915	16.333	4.111	24° 0'	240.487	2.381091	20.791	5.255
50	305.599	.485152	16.361	4.118	10	238.853	.378130	20.933	5.292
52	305.064	.484391	16.390	4.125	20	237.241	.375190	21.076	5.329
54	304.531	.483632	16.419	4.133	30	235.652	.372270	21.218	5.366
56	304.000	.482873	16.447	4.140	40	234.084	.369371	21.360	5.402
58	303.470	.482116	16.476	4.147	50	232.537	.366492	21.502	5.439
19° 0'	302.943	2.481361	16.505	4.155	25° 0'	231.011	2.363633	21.644	5.476
2	302.417	.480607	16.533	4.162	10	229.506	.360794	21.786	5.513
4	301.893	.479854	16.562	4.169	20	228.020	.357974	21.928	5.549
6	301.371	.479102	16.591	4.177	30	226.555	.355173	22.070	5.586
8	300.851	.478352	16.620	4.184	40	225.108	.352391	22.212	5.623
10	300.333	.477603	16.648	4.191	50	223.680	.349627	22.353	5.660
12	299.816	.476855	16.677	4.199	26° 0'	222.271	2.346882	22.495	5.697
14	299.302	.476109	16.706	4.206	10	220.879	.344155	22.637	5.734
16	298.789	.475364	16.734	4.213	20	219.506	.341446	22.778	5.770
18	298.278	.474621	16.763	4.221	30	218.150	.338755	22.920	5.807
20	297.768	2.473878	16.792	4.228	40	216.811	.336081	23.062	5.844
22	297.260	.473137	16.820	4.235	50	215.489	.333424	23.203	5.881
24	296.755	.472398	16.849	4.243	27° 0'	214.183	2.330785	23.345	5.918
26	296.250	.471659	16.878	4.250	10	212.893	.328162	23.486	5.955
28	295.748	.470922	16.906	4.257	20	211.620	.325556	23.627	5.992
30	295.247	.470186	16.935	4.265	30	210.362	.322967	23.769	6.029
32	294.748	.469452	16.964	4.272	40	209.119	.320393	23.910	6.065
34	294.251	.468718	16.992	4.279	50	207.891	.317836	24.051	6.102
36	293.756	.467986	17.021	4.287	28° 0'	206.678	2.315295	24.192	6.139
38	293.262	.467256	17.050	4.294	10	205.480	.312769	24.333	6.176
40	292.770	2.466526	17.078	4.301	20	204.296	.310259	24.474	6.213
42	292.279	.465798	17.107	4.308	30	203.125	.307764	24.615	6.250
44	291.790	.465071	17.136	4.316	40	201.969	.305285	24.756	6.287
46	291.303	.464345	17.164	4.323	50	200.826	.302820	24.897	6.324
48	290.818	.463621	17.193	4.330	29° 0'	199.696	2.300370	25.038	6.360
50	290.334	.462897	17.222	4.338	10	198.580	.297935	25.179	6.398
52	289.851	.462175	17.250	4.345	20	197.476	.295515	25.320	6.435
54	289.371	.461455	17.279	4.352	30	196.385	.293108	25.460	6.472
56	288.892	.460735	17.308	4.360	40	195.306	.290716	25.601	6.509
58	288.414	.460017	17.336	4.367	50	194.240	.288338	25.741	6.545
60	287.939	2.459300	17.365	4.374	30° 0'	193.185	2.285974	25.882	6.583

TABLE I.—RADII, LOGARITHMS, OFFSETS, ETC. 9

Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Loga- rithm. log. R.	Tang. Off. t.	Mid. Ord. m.
30° 20'	191.111	2.281286	26.163	6.657	38° 30'	151.657	2.180863	32.969	8.479
40	189.083	.276652	26.443	6.731	39° 0'	149.787	.175475	33.381	8.592
31° 0'	187.099	.272071	26.724	6.805	30	147.965	.170160	33.792	8.704
20	185.158	.267541	27.004	6.879	40° 0'	146.190	.164918	34.202	8.816
40	183.258	.263062	27.284	6.953	30	144.460	.159747	34.612	8.929
32° 0'	181.398	.258632	27.564	7.027	41° 0'	142.773	.154645	35.021	9.041
20	179.577	.254250	27.843	7.101	30	141.127	.149610	35.429	9.154
40	177.794	.249916	28.123	7.175	42° 0'	139.521	.144641	35.837	9.267
33° 0'	176.047	.245628	28.402	7.250	30	137.955	.139736	36.244	9.380
20	174.336	.241386	28.680	7.324	43° 0'	136.425	.134895	36.650	9.493
40	172.659	.237188	28.959	7.398	30	134.932	.130114	37.056	9.606
34° 0'	171.015	2.233035	29.237	7.473	44° 0'	133.473	2.125395	37.461	9.719
20	169.404	.228924	29.515	7.547	30	132.049	.120734	37.865	9.832
40	167.825	.224855	29.793	7.621	45° 0'	130.656	.116130	38.268	9.946
35° 0'	166.275	.220828	30.071	7.696	30	129.296	.111584	38.671	10.059
20	164.756	.216842	30.348	7.770	46° 0'	127.965	.107092	39.073	10.173
40	163.266	.212895	30.625	7.845	30	126.664	.102655	39.474	10.286
36° 0'	161.803	.208988	30.902	7.919	47° 0'	125.392	.098270	39.875	10.400
20	160.368	.205119	31.178	7.994	30	124.148	.093938	40.275	10.514
40	158.960	.201288	31.454	8.068	48° 0'	122.930	.089657	40.674	10.628
37° 0'	157.577	.197494	31.730	8.143	30	121.738	.085425	41.072	10.742
20	156.220	.193736	32.006	8.218	49° 0'	120.571	.081243	41.469	10.856
40	154.887	.190014	32.282	8.292	30	119.429	.077109	41.866	10.970
38° 0'	153.578	2.186328	32.557	8.367	50° 0'	118.310	2.073022	42.262	11.085

TABLE II.—CORRECTIONS FOR TANGENTS AND EXTERNALS

Ang Δ	FOR TANGENTS, ADD						Ang Δ	FOR EXTERNALS, ADD					
	5° Cur.	10° Cur.	15° Cur.	20° Cur.	25° Cur.	30° Cur.		5° Cur.	10° Cur.	15° Cur.	20° Cur.	25° Cur.	30° Cur.
10°	.03	.06	.09	.13	.16	.19	10°	.001	.003	.004	.006	.007	.008
20	.06	.13	.19	.26	.32	.39	20	.006	.011	.017	.022	.028	.034
30	.10	.19	.29	.39	.49	.59	30	.013	.025	.038	.051	.065	.078
40	.13	.26	.40	.53	.67	.80	40	.023	.046	.070	.093	.117	.141
50	.17	.34	.51	.68	.85	1.02	50	.037	.075	.116	.151	.189	.227
60	.21	.42	.63	.84	1.05	1.27	60	.056	.112	.168	.225	.283	.340
70	.25	.51	.76	1.02	1.28	1.54	70	.080	.159	.240	.321	.403	.485
80	.30	.61	.91	1.22	1.53	1.84	80	.110	.220	.332	.445	.558	.671
90	.36	.72	1.09	1.45	1.83	2.20	90	.149	.299	.450	.603	.756	.910
100	.43	.86	1.30	1.74	2.18	2.62	100	.200	.401	.604	.809	1.015	1.221
110	.51	1.03	1.56	2.08	2.61	3.14	110	.268	.536	.806	1.082	1.355	1.633
120	.52	1.25	1.93	2.52	3.16	3.81	120	.360	.721	1.086	1.456	1.825	2.197

Angle. Δ	Tan- gent. T.	Exter- nal. E.	Angle. Δ	Tan- gent. T.	Exter- nal. E.	Angle. Δ	Tan- gent. T.	Exter- nal. E.
1°	50.00	.218	11	551.70	26.500	21°	1061.9	97.577
10	58.34	.297	10'	560.11	27.313	10'	1070.6	99.155
20	66.67	.388	20	568.53	28.137	20	1079.2	100.75
30	75.01	.491	30	576.95	28.974	30	1087.8	102.35
40	83.34	.606	40	585.36	29.824	40	1096.4	103.97
50	91.68	.733	50	593.79	30.686	50	1105.1	105.60
2	100.01	.873	12	602.21	31.561	22	1113.7	107.24
10	108.35	1.024	10	610.64	32.447	10	1122.4	108.90
20	116.68	1.188	20	619.07	33.347	20	1131.0	110.57
30	125.02	1.364	30	627.50	34.259	30	1139.7	112.25
40	133.36	1.552	40	635.93	35.183	40	1148.4	113.95
50	141.70	1.752	50	644.37	36.120	50	1157.0	115.66
3	150.04	1.964	13	652.81	37.070	23	1165.7	117.38
10	158.38	2.188	10	661.25	38.031	10	1174.4	119.12
20	166.72	2.425	20	669.70	39.006	20	1183.1	120.87
30	175.06	2.674	30	678.15	39.993	30	1191.8	122.63
40	183.40	2.934	40	686.60	40.992	40	1200.5	124.41
50	191.74	3.207	50	695.06	42.004	50	1209.2	126.20
4	200.08	3.492	14	703.51	43.029	24	1217.9	128.00
10	208.43	3.790	10	711.97	44.066	10	1226.6	129.82
20	216.77	4.099	20	720.44	45.116	20	1235.3	131.65
30	225.12	4.421	30	728.90	46.178	30	1244.0	133.50
40	233.47	4.755	40	737.37	47.253	40	1252.8	135.35
50	241.81	5.100	50	745.85	48.341	50	1261.5	137.23
5	250.16	5.459	15	754.32	49.441	25	1270.2	139.11
10	258.51	5.829	10	762.80	50.554	10	1279.0	141.01
20	266.86	6.211	20	771.29	51.679	20	1287.7	142.93
30	275.21	6.606	30	779.77	52.818	30	1296.5	144.85
40	283.57	7.013	40	788.26	53.969	40	1305.3	146.79
50	291.92	7.432	50	796.75	55.132	50	1314.0	148.75
6	300.28	7.863	16	805.25	56.309	26	1322.8	150.71
10	308.64	8.307	10	813.75	57.498	10	1331.6	152.69
20	316.99	8.762	20	822.25	58.699	20	1340.4	154.69
30	325.35	9.230	30	830.76	59.914	30	1349.2	156.70
40	333.71	9.710	40	839.27	61.141	40	1358.0	158.72
50	342.08	10.202	50	847.78	62.381	50	1366.8	160.76
7	350.44	10.707	17	856.30	63.634	27	1375.6	162.81
10	358.81	11.224	10	864.82	64.900	10	1384.4	164.86
20	367.17	11.753	20	873.35	66.178	20	1393.2	166.95
30	375.54	12.294	30	881.88	67.470	30	1402.0	169.04
40	383.91	12.847	40	890.41	68.774	40	1410.9	171.15
50	392.28	13.413	50	898.95	70.091	50	1419.7	173.27
8	400.66	13.991	18	907.49	71.421	28	1428.6	175.41
10	409.03	14.582	10	916.03	72.764	10	1437.4	177.55
20	417.41	15.184	20	924.58	74.119	20	1446.3	179.72
30	425.79	15.799	30	933.13	75.488	30	1455.1	181.89
40	434.17	16.426	40	941.69	76.869	40	1464.0	184.08
50	442.55	17.065	50	950.25	78.264	50	1472.9	186.29
9	450.93	17.717	19	958.81	79.671	29	1481.8	188.51
10	459.32	18.381	10	967.38	81.092	10	1490.7	190.74
20	467.71	19.058	20	975.96	82.525	20	1499.6	192.99
30	476.10	19.746	30	984.53	83.972	30	1508.5	195.25
40	484.49	20.447	40	993.12	85.431	40	1517.4	197.53
50	492.88	21.161	50	1001.7	86.904	50	1526.3	199.82
10	501.28	21.887	20	1010.3	88.389	30	1535.3	202.12
10	509.68	22.624	10	1018.9	89.888	10	1544.2	204.44
20	518.08	23.375	20	1027.5	91.399	20	1553.1	206.77
30	526.48	24.138	30	1036.1	92.924	30	1562.1	209.12
40	534.89	24.913	40	1044.7	94.462	40	1571.0	211.48
50	543.29	25.700	50	1053.3	96.013	50	1580.0	213.86

Angle. Δ	Tan- gent. T.	Exter- nal. E.	Angle. Δ	Tan- gent. T.	Exter- nal. E.	Angle. Δ	Tan- gent. T.	Exter- nal. E.
31°	1589.0	216.25	41°	2142.2	387.38	51°	2732.9	618.39
10	1598.0	218.66	10'	2151.7	390.71	10'	2743.1	622.81
20	1606.9	221.08	20	2161.2	394.06	20	2753.4	627.24
30	1615.9	223.51	30	2170.8	397.43	30	2763.7	631.69
40	1624.9	225.96	40	2180.3	400.82	40	2773.9	636.17
50	1633.9	228.42	50	2189.9	404.22	50	2784.2	640.66
32	1643.0	230.90	42	2199.4	407.64	52	2794.5	645.17
10	1652.0	233.39	10	2209.0	411.07	10	2804.9	649.70
20	1661.0	235.90	20	2218.6	414.52	20	2815.2	654.25
30	1670.0	238.43	30	2228.1	417.99	30	2825.6	658.83
40	1679.1	240.96	40	2237.7	421.48	40	2835.9	663.42
50	1688.1	243.52	50	2247.3	424.98	50	2846.3	668.03
33	1697.2	246.08	43	2257.0	428.50	53	2856.7	672.66
10	1706.3	248.66	10	2266.6	432.04	10	2867.1	677.32
20	1715.3	251.26	20	2276.2	435.59	20	2877.5	681.99
30	1724.4	253.87	30	2285.9	439.16	30	2888.0	686.68
40	1733.5	256.50	40	2295.6	442.75	40	2898.4	691.40
50	1742.6	259.14	50	2305.2	446.35	50	2908.9	696.13
34	1751.7	261.80	44	2314.9	449.98	54	2919.4	700.89
10	1760.8	264.47	10	2324.6	453.62	10	2929.9	705.66
20	1770.0	267.16	20	2334.3	457.27	20	2940.4	710.46
30	1779.1	269.86	30	2344.1	460.95	30	2951.0	715.28
40	1788.2	272.58	40	2353.8	464.64	40	2961.5	720.11
50	1797.4	275.31	50	2363.5	468.35	50	2972.1	724.97
35	1806.6	278.05	45	2373.3	472.08	55	2982.7	729.85
10	1815.7	280.82	10	2383.1	475.82	10	2993.3	734.76
20	1824.9	283.60	20	2392.8	479.59	20	3003.9	739.68
30	1834.1	286.39	30	2402.6	483.37	30	3014.5	744.62
40	1843.3	289.20	40	2412.4	487.17	40	3025.2	749.59
50	1852.5	292.02	50	2422.3	490.98	50	3035.8	754.57
36	1861.7	294.86	46	2432.1	494.82	56	3046.5	759.58
10	1870.9	297.72	10	2441.9	498.67	10	3057.2	764.61
20	1880.1	300.59	20	2451.8	502.54	20	3067.9	769.66
30	1889.4	303.47	30	2461.7	506.42	30	3078.7	774.73
40	1896.6	306.37	40	2471.5	510.33	40	3089.4	779.83
50	1907.9	309.29	50	2481.4	514.25	50	3100.2	784.94
37	1917.1	312.22	47	2491.3	518.20	57	3110.9	790.08
10	1926.4	315.17	10	2501.2	522.16	10	3121.7	795.24
20	1935.7	318.13	20	2511.2	526.13	20	3132.6	800.42
30	1945.0	321.11	30	2521.1	530.13	30	3143.4	805.62
40	1954.3	324.11	40	2531.1	534.15	40	3154.2	810.85
50	1963.6	327.12	50	2541.0	538.18	50	3165.1	816.10
38	1972.9	330.15	48	2551.0	542.23	58	3176.0	821.37
10	1982.2	333.19	10	2561.0	546.30	10	3186.9	826.66
20	1991.5	336.25	20	2571.0	550.39	20	3197.8	831.98
30	2000.9	339.32	30	2581.0	554.50	30	3208.8	837.31
40	2010.2	342.41	40	2591.1	558.63	40	3219.7	842.67
50	2019.6	345.52	50	2601.1	562.77	50	3230.7	848.06
39	2029.0	348.64	49	2611.2	566.94	59	3241.7	853.46
10	2038.4	351.78	10	2621.2	571.12	10	3252.7	858.89
20	2047.8	354.94	20	2631.3	575.32	20	3263.7	864.34
30	2057.2	358.11	30	2641.4	579.54	30	3274.8	869.82
40	2066.6	361.29	40	2651.5	583.78	40	3285.8	875.32
50	2076.0	364.50	50	2661.6	588.04	50	3296.9	880.84
40	2085.4	367.72	50	2671.8	592.32	60	3308.0	886.38
10	2094.9	370.95	10	2681.9	596.62	10	3319.1	891.95
20	2104.3	374.20	20	2692.1	600.93	20	3330.3	897.54
30	2113.8	377.47	30	2702.3	605.27	30	3341.4	903.15
40	2123.3	380.76	40	2712.5	609.62	40	3352.6	908.79
50	2132.7	384.06	50	2722.7	614.00	50	3363.8	914.45

Angle. Δ	Tan- gent. T.	Exter- nal. E.	Angle. Δ	Tan- gent. T.	Exter- nal. E.	Angle. Δ	Tan- gent. T.	Exter- nal. E.
61°	3375.0	920.14	71°	4086.9	1308.2	81°	4893.6	1805.3
10'	3386.3	925.85	10'	4099.5	1315.6	10'	4908.0	1814.7
20	3397.5	931.58	20	4112.1	1322.9	20	4922.5	1824.1
30	3408.8	937.34	30	4124.8	1330.3	30	4937.0	1833.6
40	3420.1	943.12	40	4137.4	1337.7	40	4951.5	1843.1
50	3431.4	948.92	50	4150.1	1345.1	50	4966.1	1852.6
62	3442.7	954.75	72	4162.8	1352.6	82	4980.7	1862.2
10	3454.1	960.60	10	4175.6	1360.1	10	4995.4	1871.8
20	3465.4	966.48	20	4188.4	1367.6	20	5010.0	1881.5
30	3476.8	972.38	30	4201.2	1375.2	30	5024.8	1891.2
40	3488.3	978.31	40	4214.0	1382.8	40	5039.5	1900.9
50	3499.7	984.27	50	4226.8	1390.4	50	5054.3	1910.7
63	3511.1	990.24	73	4239.7	1398.0	83	5069.2	1920.5
10	3522.6	996.24	10	4252.6	1405.7	10	5084.0	1930.4
20	3534.1	1002.3	20	4265.6	1413.5	20	5099.0	1940.3
30	3545.6	1008.3	30	4278.5	1421.2	30	5113.9	1950.3
40	3557.2	1014.4	40	4291.5	1429.0	40	5128.9	1960.2
50	3568.7	1020.5	50	4304.6	1436.8	50	5143.9	1970.3
64	3580.3	1026.6	74	4317.6	1444.6	84	5159.0	1980.4
10	3591.9	1032.8	10	4330.7	1452.5	10	5174.1	1990.5
20	3603.5	1039.0	20	4343.8	1460.4	20	5189.3	2000.6
30	3615.1	1045.2	30	4356.9	1468.4	30	5204.4	2010.8
40	3626.8	1051.4	40	4370.1	1476.4	40	5219.7	2021.1
50	3638.5	1057.7	50	4383.3	1484.4	50	5234.9	2031.4
65	3650.2	1063.9	75	4396.5	1492.4	85	5250.3	2041.7
10	3661.9	1070.2	10	4409.8	1500.5	10	5265.6	2052.1
20	3673.7	1076.6	20	4423.1	1508.6	20	5281.0	2062.5
30	3685.4	1082.9	30	4436.4	1516.7	30	5296.4	2073.0
40	3697.2	1089.3	40	4449.7	1524.9	40	5311.9	2083.5
50	3709.0	1095.7	50	4463.1	1533.1	50	5327.4	2094.1
66	3720.9	1102.2	76	4476.5	1541.4	86	5343.0	2104.7
10	3732.7	1108.6	10	4489.9	1549.7	10	5358.6	2115.3
20	3744.6	1115.1	20	4503.4	1558.0	20	5374.2	2126.0
30	3756.5	1121.7	30	4516.9	1566.3	30	5389.9	2136.7
40	3768.5	1128.2	40	4530.4	1574.7	40	5405.6	2147.5
50	3780.4	1134.8	50	4544.0	1583.1	50	5421.4	2158.4
67	3792.4	1141.4	77	4557.6	1591.6	87	5437.2	2169.2
10	3804.4	1148.0	10	4571.2	1600.1	10	5453.1	2180.2
20	3816.4	1154.7	20	4584.8	1608.6	20	5469.0	2191.1
30	3828.4	1161.3	30	4598.5	1617.1	30	5484.9	2202.2
40	3840.5	1168.1	40	4612.2	1625.7	40	5500.9	2213.2
50	3852.6	1174.8	50	4626.0	1634.4	50	5517.0	2224.3
68	3864.7	1181.6	78	4639.8	1643.0	88	5533.1	2235.5
10	3876.8	1188.4	10	4653.6	1651.7	10	5549.2	2246.7
20	3889.0	1195.2	20	4667.4	1660.5	20	5565.4	2258.0
30	3901.2	1202.0	30	4681.3	1669.2	30	5581.6	2269.3
40	3913.4	1208.9	40	4695.2	1678.1	40	5597.8	2280.6
50	3925.6	1215.8	50	4709.2	1686.9	50	5614.2	2292.0
69	3937.9	1222.7	79	4723.2	1695.8	89	5630.5	2303.5
10	3950.2	1229.7	10	4737.2	1704.7	10	5646.9	2315.0
20	3962.5	1236.7	20	4751.2	1713.7	20	5663.4	2326.6
30	3974.8	1243.7	30	4765.3	1722.7	30	5679.9	2338.2
40	3987.2	1250.8	40	4779.4	1731.7	40	5696.4	2349.8
50	3999.5	1257.9	50	4793.6	1740.8	50	5713.0	2361.5
70	4011.9	1265.0	80	4807.7	1749.9	90	5729.7	2373.3
10	4024.4	1272.1	10	4822.0	1759.0	10	5746.3	2385.1
20	4036.8	1279.3	20	4836.2	1768.2	20	5763.1	2397.0
30	4049.3	1286.5	30	4850.5	1777.4	30	5779.9	2408.9
40	4061.8	1293.6	40	4864.8	1786.7	40	5796.7	2420.9
50	4074.4	1300.9	50	4879.2	1796.0	50	5813.6	2432.9

Angle. Δ	Tan- gent. T.	Ex- ternal. E.	Angle. Δ	Tan- gent. T.	Ex- ternal. E.	Angle. Δ	Tan- gent. T.	Ex- ternal. E.
91°	5830.5	2444.9	101°	6950.6	3278.1	111°	8336.7	4386.1
10'	5847.5	2457.1	10'	6971.3	3294.1	10'	8362.7	4407.6
20	5864.6	2469.3	20	6992.0	3310.1	20	8388.9	4429.2
30	5881.7	2481.5	30	7012.7	3326.1	30	8415.1	4450.9
40	5898.8	2493.8	40	7033.6	3342.3	40	8441.5	4472.7
50	5916.0	2506.1	50	7054.5	3358.5	50	8468.0	4494.6
92	5933.2	2518.5	102	7075.5	3374.9	112	8494.6	4516.6
10	5950.5	2531.0	10	7096.6	3391.2	10	8521.3	4538.8
20	5967.9	2543.5	20	7117.8	3407.7	20	8548.1	4561.1
30	5985.3	2556.0	30	7139.0	3424.3	30	8575.0	4583.4
40	6002.7	2568.6	40	7160.3	3440.9	40	8602.1	4606.0
50	6020.2	2581.3	50	7181.7	3457.6	50	8629.3	4628.6
93	6037.8	2594.0	103	7203.2	3474.4	113	8656.6	4651.3
10	6055.4	2606.8	10	7224.7	3491.3	10	8684.0	4674.2
20	6073.1	2619.7	20	7246.3	3508.2	20	8711.5	4697.2
30	6090.8	2632.6	30	7268.0	3525.2	30	8739.2	4720.3
40	6108.6	2645.5	40	7289.8	3542.4	40	8767.0	4743.6
50	6126.4	2658.5	50	7311.7	3559.6	50	8794.9	4766.9
94	6144.3	2671.6	104	7333.6	3576.8	114	8822.9	4790.4
10	6162.2	2684.7	10	7355.6	3594.2	10	8851.0	4814.1
20	6180.2	2697.9	20	7377.8	3611.7	20	8879.3	4837.8
30	6198.3	2711.2	30	7399.9	3629.2	30	8907.7	4861.7
40	6216.4	2724.5	40	7422.2	3646.8	40	8936.3	4885.7
50	6234.6	2737.9	50	7444.6	3664.5	50	8965.0	4909.9
95	6252.8	2751.3	105	7467.0	3682.3	115	8993.8	4934.1
10	6271.1	2764.8	10	7489.6	3700.2	10	9022.7	4958.6
20	6289.4	2778.3	20	7512.2	3718.2	20	9051.7	4983.1
30	6307.9	2792.0	30	7534.9	3736.2	30	9080.9	5007.8
40	6326.3	2805.6	40	7557.7	3754.4	40	9110.3	5032.6
50	6344.8	2819.4	50	7580.5	3772.6	50	9139.8	5057.6
96	6363.4	2833.2	106	7603.5	3791.0	116	9169.4	5082.7
10	6382.1	2847.0	10	7626.6	3809.4	10	9199.1	5107.9
20	6400.8	2861.0	20	7649.7	3827.9	20	9229.0	5133.3
30	6419.5	2875.0	30	7672.9	3846.5	30	9259.0	5158.8
40	6438.4	2889.0	40	7696.3	3865.2	40	9289.2	5184.5
50	6457.3	2903.1	50	7719.7	3884.0	50	9319.5	5210.3
97	6476.2	2917.3	107	7743.2	3902.9	117	9349.9	5236.2
10	6495.2	2931.6	10	7766.8	3921.9	10	9380.5	5262.3
20	6514.3	2945.9	20	7790.5	3940.9	20	9411.3	5288.6
30	6533.4	2960.3	30	7814.3	3960.1	30	9442.2	5315.0
40	6552.6	2974.7	40	7838.1	3979.4	40	9473.2	5341.5
50	6571.9	2989.2	50	7862.1	3998.7	50	9504.4	5368.2
98	6591.2	3003.8	108	7886.2	4018.2	118	9535.7	5395.1
10	6610.6	3018.4	10	7910.4	4037.8	10	9567.2	5422.1
20	6630.1	3033.1	20	7934.6	4057.4	20	9598.9	5449.2
30	6649.6	3047.9	30	7959.0	4077.2	30	9630.7	5476.5
40	6669.2	3062.8	40	7983.5	4097.1	40	9662.6	5504.0
50	6688.8	3077.7	50	8008.0	4117.0	50	9694.7	5531.7
99	6708.6	3092.7	109	8032.7	4137.1	119	9727.0	5559.4
10	6728.4	3107.7	10	8057.4	4157.3	10	9759.4	5587.4
20	6748.2	3122.9	20	8082.3	4177.5	20	9792.0	5615.5
30	6768.1	3138.1	30	8107.3	4197.9	30	9824.8	5643.8
40	6788.1	3153.3	40	8132.3	4218.4	40	9857.7	5672.3
50	6808.2	3168.7	50	8157.5	4239.0	50	9890.8	5700.9
100	6828.3	3184.1	110	8182.8	4259.7	120	9924.0	5729.7
10	6848.5	3199.6	10	8208.2	4280.5	10	9957.5	5758.6
20	6868.8	3215.1	20	8233.7	4301.4	20	9991.0	5787.7
30	6889.2	3230.8	30	8259.3	4322.4	30	10025.0	5817.0
40	6909.6	3246.5	40	8285.0	4343.6	40	10059.0	5846.5
50	6930.1	3262.3	50	8310.8	4364.8	50	10093.0	5876.1

Degree of Curve.	Actual Arc, One Station.	LONG CHORDS.				
		3 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
0° 10'	100.000	200.000	299.999	399.998	499.996	599.993
20	.000	199.999	299.997	399.992	499.983	599.970
30	.000	199.998	299.992	399.981	499.962	599.933
40	.001	199.997	299.986	399.966	499.932	599.882
50	.001	199.995	299.979	399.947	499.894	599.815
1 10	100.001	199.992	299.970	399.924	499.848	599.733
20	.002	199.990	299.959	399.896	499.793	599.637
30	.003	199.986	299.946	399.865	499.729	599.526
40	.003	199.983	299.932	399.829	499.657	599.401
50	.003	199.979	299.915	399.789	499.577	599.260
	.004	199.974	299.898	399.744	499.488	599.105
2 10	100.005	199.970	299.878	399.695	499.391	598.934
20	.006	199.964	299.857	399.643	499.285	598.750
30	.007	199.959	299.834	399.586	499.171	598.550
40	.008	199.952	299.810	399.524	499.049	598.336
50	.009	199.946	299.783	399.459	498.918	598.106
3 10	100.011	199.939	299.756	399.389	498.778	597.862
20	.013	199.931	299.726	399.315	498.630	597.604
30	.014	199.924	299.695	399.237	498.474	597.331
40	.015	199.915	299.662	399.154	498.309	597.043
50	.017	199.907	299.627	399.068	498.136	596.740
	.019	199.898	299.591	398.977	497.955	596.423
		199.888	299.553	398.882	497.765	596.091
4 10	100.020	199.878	299.513	398.782	497.566	595.744
20	.022	199.868	299.471	398.679	497.360	595.383
30	.024	199.857	299.428	398.571	497.145	595.007
40	.026	199.846	299.383	398.459	496.921	594.617
50	.028	199.834	299.337	398.343	496.689	594.212
5 10	100.030	199.822	299.289	398.223	496.449	593.792
20	.032	199.810	299.239	398.099	496.201	593.358
30	.034	199.797	299.187	397.970	495.944	592.909
40	.036	199.783	299.134	397.837	495.678	592.446
50	.038	199.770	299.079	397.700	495.405	591.968
	.041	199.756	299.023	397.559	495.123	591.476
	.043	199.741	298.964	397.413	494.832	590.970
6 10	100.046	199.726	298.904	397.264	494.534	590.449
20	.048	199.710	298.843	397.110	494.227	589.913
30	.051	199.695	298.779	396.952	493.912	589.364
40	.054	199.678	298.714	396.790	493.588	588.800
50	.056	199.662	298.648	396.623	493.257	588.221
7 10	100.059	199.644	298.579	396.453	492.917	587.628
20	.062	199.627	298.509	396.278	492.568	587.021
30	.065	199.609	298.438	396.099	492.212	586.400
40	.068	199.591	298.364	395.916	491.847	585.765
50	.071	199.572	298.289	395.729	491.474	585.115
	.075	199.553	298.212	395.538	491.098	584.451
	.078	199.533	298.134	395.342	490.704	583.773
8 10	100.081	199.513	298.054	395.142	490.306	583.081
20	.085	199.492	297.972	394.938	489.900	582.375
30	.088	199.471	297.888	394.731	489.486	581.654
40	.092	199.450	297.803	394.518	489.064	580.920
50	.095	199.428	297.716	394.302	488.634	580.172
9 10	100.099	199.406	297.628	394.082	488.196	579.409
20	.103	199.383	297.538	393.857	487.749	578.633
30	.107	199.360	297.446	393.629	487.294	577.843
40	.111	199.337	297.352	393.396	486.832	577.039
50	.115	199.313	297.257	393.159	486.361	576.222
	.119	199.289	297.160	392.918	485.882	575.390
	.123	199.264	297.062	392.673	485.395	574.545
10 10	100.127	199.239	296.962	392.424	484.900	573.686

Degree of Curve.	LONG CHORDS.					
	7 Stations.	8 Stations.	9 Stations.	10 Stations.	11 Stations.	12 Stations.
0° 10	699.988	799.982	899.974	999.965	1099.95	1199.94
20	699.953	799.929	899.899	999.860	1099.81	1199.76
30	699.893	799.840	899.772	999.686	1099.58	1199.46
40	699.810	799.716	899.594	999.442	1099.25	1199.03
50	699.704	799.556	899.365	999.128	1098.84	1198.49
1 10	699.574	799.360	899.086	998.744	1098.33	1197.82
20	699.420	799.130	898.757	998.290	1097.72	1197.04
30	699.242	798.803	898.376	997.768	1097.02	1196.13
40	699.041	798.562	897.945	997.175	1096.23	1195.11
50	698.816	798.224	897.464	996.513	1095.35	1193.96
	698.567	797.852	896.931	995.782	1094.38	1192.69
2 10	698.295	797.444	896.349	994.981	1093.31	1191.31
20	698.000	797.000	895.716	994.112	1092.15	1189.80
30	697.680	796.522	895.033	993.173	1090.90	1188.18
40	697.338	796.008	894.299	992.165	1089.56	1186.43
50	696.971	795.459	893.515	991.088	1088.12	1184.57
3 10	696.581	794.874	892.681	989.943	1086.60	1182.59
20	696.168	794.255	891.798	988.729	1084.98	1180.49
30	695.731	793.600	890.864	987.447	1083.23	1178.28
40	695.271	792.911	889.880	986.096	1081.48	1175.94
50	694.787	792.186	888.846	984.677	1079.59	1173.49
	694.280	791.427	887.763	983.190	1077.61	1170.93
	693.750	790.632	886.630	981.636	1075.54	1168.25
4 10	693.196	789.803	885.448	980.014	1073.38	1165.45
20	692.619	788.939	884.217	978.325	1071.14	1162.54
30	692.018	788.040	882.936	976.569	1068.81	1159.51
40	691.395	787.108	881.606	974.746	1066.38	1156.37
50	690.748	786.140	880.228	972.856	1063.87	1153.12
5 10	690.079	785.138	878.800	970.900	1061.27	1149.76
20	689.386	784.101	877.324	968.877	1058.59	1146.28
30	688.670	783.030	875.800	966.788	1055.81	1142.69
40	687.930	781.925	874.227	964.634	1052.95	1138.99
50	687.169	780.786	872.605	962.415	1050.01	1135.18
	686.384	779.612	870.936	960.130	1046.97	1131.26
	685.576	778.406	869.219	957.780	1043.86	1127.24
6 10	684.745	777.165	867.454	955.366	1040.66	1123.10
20	683.892	775.890	865.642	952.888	1037.37	1118.86
30	683.016	774.582	863.782	950.345	1034.01	1114.51
40	682.117	773.240	861.875	947.739	1030.55	1110.05
50	681.195	771.864	859.922	945.069	1027.02	1105.49
7 10	680.251	770.455	857.921	942.337	1023.40	1100.83
20	679.285	769.014	855.874	939.542	1019.70	1096.06
30	678.296	767.539	853.780	936.684	1015.93	1091.19
40	677.284	766.030	851.640	933.764	1012.07	1086.22
50	676.250	764.490	849.455	930.783	1008.13	1081.15
	675.194	762.916	847.224	927.741	1004.11	1075.98
	674.116	761.309	844.947	924.638	1000.01	1070.71
8 10	673.015	759.670	842.625	921.474	995.834	1065.34
20	671.892	757.999	840.258	918.250	991.580	1059.88
30	670.748	756.295	837.845	914.966	987.250	1054.32
40	669.581	754.560	835.389	911.623	982.844	1048.66
50	668.393	752.792	832.888	908.221	978.362	1042.91
9 10	667.182	750.993	830.342	904.761	973.806	1037.06
20	665.950	749.161	827.754	901.242	969.175	1031.13
30	664.697	747.299	825.121	897.667	964.471	1025.11
40	663.421	745.404	822.445	894.033	959.694	1018.99
50	662.124	743.479	819.726	890.343	954.844	1012.79
	660.806	741.522	816.965	886.597	949.924	1006.49
	659.466	739.535	814.160	882.795	944.983	1000.12
10 10	658.105	737.516	811.314	878.938	939.871	993.653

Degree of Curve.	Actual Arc, One Station.	LONG CHORDS.				
		2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
10°	10'	100.131	199.213	296.860	392.171	484.397
	20	.136	199.187	296.756	391.914	483.886
	30	.140	199.161	296.651	391.652	483.367
	40	.145	199.134	296.544	391.387	482.840
	50	.149	199.107	296.436	391.117	482.305
11	100.154	199.079	296.325	390.843	481.762	568.245
	10	.158	199.051	296.214	390.565	481.211
	20	.163	199.023	296.100	390.284	480.653
	30	.168	198.994	295.985	389.998	480.086
	40	.173	198.964	295.868	389.708	479.511
	50	.178	198.935	295.750	389.414	478.929
12	100.183	198.904	295.629	389.116	478.338	562.321
	10	.188	198.874	295.508	388.814	477.740
	20	.193	198.843	295.384	388.508	477.135
	30	.199	198.811	295.259	388.197	476.521
	40	.204	198.779	295.132	387.883	475.899
	50	.209	198.747	295.004	387.565	475.270
13	100.215	198.714	294.874	387.243	474.633	555.921
	10	.220	198.681	294.742	386.916	473.988
	20	.226	198.648	294.609	386.586	473.336
	30	.232	198.614	294.474	386.252	472.675
	40	.237	198.579	294.337	385.914	472.007
	50	.243	198.544	294.199	385.572	471.332
14	100.249	198.509	294.059	385.225	470.649	549.056
	10	.255	198.474	293.918	384.875	469.958
	20	.261	198.437	293.774	384.521	469.260
	30	.267	198.401	293.629	384.163	468.554
	40	.274	198.364	293.483	383.801	467.840
	50	.280	198.327	293.335	383.435	467.119
15	100.286	198.289	293.185	383.065	466.390	541.736
	10	.292	198.251	293.034	382.691	465.654
	20	.299	198.212	292.881	382.313	464.911
	30	.306	198.173	292.726	381.931	464.160
	40	.312	198.134	292.570	381.546	463.401
	50	.319	198.094	292.412	381.156	462.635
16	100.326	198.054	292.252	380.763	461.862	533.972
	10	.333	198.013	292.091	380.365	461.061
	20	.339	197.972	291.928	379.964	460.293
	30	.346	197.930	291.764	379.559	459.498
	40	.353	197.888	291.598	379.150	458.695
	50	.361	197.846	291.430	378.737	457.886
17	100.368	197.803	291.261	378.320	457.069	525.776
	10	.375	197.760	291.090	377.900	456.244
	20	.382	197.716	290.918	377.475	455.413
	30	.390	197.672	290.743	377.047	454.574
	40	.397	197.628	290.568	376.615	453.728
	50	.405	197.583	290.390	376.179	452.875
18	100.412	197.538	290.211	375.739	452.015	517.160
	10	.420	197.492	290.031	375.295	451.147
	20	.428	197.446	289.849	374.848	450.273
	30	.436	197.399	289.665	374.397	449.392
	40	.444	197.352	289.479	373.942	448.504
	50	.452	197.305	289.292	373.483	447.608
19	100.460	197.256	289.104	373.021	446.706	508.139
	10	.468	197.209	288.913	372.554	445.797
	20	.476	197.160	288.722	372.084	444.881
	30	.484	197.111	288.528	371.610	443.957
	40	.493	197.062	288.333	371.133	443.028
	50	.501	197.012	288.137	370.652	442.091
20	100.510	196.962	287.939	370.167	441.147	498.724

Degree of Curve.	LONG CHORDS.					
	7 Stations.	8 Stations.	9 Stations.	10 Stations.	11 Stations.	12 Stations.
10°						
10	656.723	735.467	808.426	875.025	934.741	987.105
20	655.320	733.387	805.495	871.058	929.542	980.473
30	653.895	731.277	802.524	867.038	924.276	973.760
40	652.450	729.137	799.512	862.963	918.943	966.967
50	650.983	726.967	796.458	858.836	913.544	960.093
11						
10	649.496	724.767	793.364	854.656	908.080	953.141
20	647.989	722.537	790.230	850.425	902.550	946.112
30	646.460	720.278	787.056	846.140	896.957	939.007
40	644.911	717.990	783.843	841.808	891.303	931.828
50	643.342	715.672	780.590	837.424	885.586	924.575
	641.752	713.325	777.298	832.990	879.807	917.250
12						
10	640.142	710.950	773.968	828.507	873.968	909.854
20	638.512	708.546	770.600	823.974	868.070	902.389
30	636.862	706.113	767.193	819.394	862.113	894.855
40	635.191	703.653	763.749	814.766	856.099	887.254
50	633.501	701.164	760.268	810.092	850.028	879.588
13						
10	631.792	698.647	756.749	805.370	843.900	871.857
20	630.062	696.103	753.194	800.602	837.718	864.063
30	628.313	693.531	749.603	795.790	831.482	856.208
40	626.544	690.932	745.976	790.932	825.192	848.293
50	624.756	688.306	742.313	786.030	818.850	840.318
	622.949	685.653	738.616	781.085	812.457	832.286
	621.123	682.974	734.883	776.096	806.013	824.198
14						
10	619.278	680.268	731.116	771.066	799.520	816.056
20	617.413	677.535	727.315	765.993	792.979	807.860
30	615.530	674.777	723.480	760.879	786.389	799.612
40	613.628	671.993	719.612	755.725	779.753	791.313
50	611.708	669.183	715.711	750.531	773.072	782.966
15						
10	609.769	666.348	711.777	745.297	766.345	774.571
20	607.812	663.488	707.811	740.024	759.575	766.130
30	605.836	660.603	703.814	734.714	752.763	
40	603.842	657.693	699.785	729.366	745.908	
50	601.831	654.758	695.725	723.982	739.014	
	599.801	651.799	691.634	718.561	732.078	
	597.753	648.817	687.513	713.105	725.104	
16						
10	595.688	645.810	683.362	707.614	718.092	
20	593.605	642.780	679.182	702.088	711.043	
30	591.505	639.727	674.973	696.529	703.959	
40	589.388	636.650	670.735	690.938		
50	587.253	633.550	666.469	685.314		
17						
10	585.101	630.428	662.175	679.659		
20	582.933	627.283	657.854	673.972		
30	580.747	624.117	653.506	668.256		
40	578.545	620.928	649.131	662.510		
50	576.326	617.717	644.730	656.735		
	574.091	614.485	640.304	650.933		
	571.839	611.232	635.852	645.103		
18						
10	569.571	607.958	631.375	639.245		
20	567.287	604.664	626.874			
30	564.988	601.349	622.349			
40	562.673	598.013	617.801			
50	560.342	594.658	613.229			
19						
10	557.996	591.283	608.635			
20	555.634	587.888	604.018			
30	553.257	584.475	599.379			
40	550.864	581.042	594.720			
50	548.457	577.591	590.039			
	546.035	574.121	585.339			
20						
10	543.599	570.634	580.618			
20	541.147	567.128	575.877			

TABLE IV.—LONG CHORDS.

Degree of Curve.	Actual Arc, One Station.	LONG CHORDS.				
		2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
21°	100.562	196.651	286.716	367.179	435.345	488.931
22	100.617	196.325	285.437	364.060	429.305	478.775
23	100.675	195.985	284.101	360.810	423.033	468.270
24	100.735	195.630	282.709	357.433	416.535	457.433
25	100.798	195.259	281.262	353.930	409.819	446.280
26	100.863	194.874	279.759	350.303	402.691	434.827
27	100.931	194.474	278.201	346.555	395.758	423.092
28	101.002	194.059	276.589	342.688	388.428	411.092
29	101.075	193.630	274.924	338.704	380.908	398.846
30	101.152	193.185	273.205	334.607	373.205	386.370
31	101.230	192.726	271.433	330.397	365.328	373.685
32	101.312	192.252	269.610	326.078	357.284	360.808
33	101.396	191.764	267.734	321.654	349.081	347.759
34	101.482	191.261	265.808	317.125	340.729	334.556
35	101.572	190.743	263.830	312.496	332.234	321.220
36	101.664	190.211	261.803	307.768	323.607	307.768
37	101.759	189.665	259.727	302.946	314.855	294.222
38	101.857	189.104	257.602	298.032	305.987	280.600
39	101.957	188.528	255.429	293.028	297.012	266.923
40	102.060	187.939	253.209	287.938	287.939	253.209
41	102.166	187.334	250.942	282.766	278.777	239.478
42	102.275	186.716	248.629	277.514	269.535	225.750
43	102.386	186.084	246.271	272.186	260.222	212.045
44	102.500	185.437	243.868	266.784	250.848	198.380
45	102.617	184.776	241.421	261.313	241.421	184.776
46	102.737	184.101	238.932	255.775	231.952	171.251
47	102.860	183.412	236.400	250.173	222.448	157.824
48	102.985	182.709	233.826	244.512	212.920	144.512
49	103.114	181.992	231.212	238.795	203.377	131.335
50	103.245	181.262	228.558	233.025	193.828	118.310

TABLE V.—LINEAR DEFLECTION TABLE

Deflection.	100.	200.	300.	400.	500.	600.	700.	800.	900.	1000.
30'	0.87	1.75	2.62	3.49	4.36	5.24	6.11	6.98	7.85	8.73
1°	1.75	3.49	5.24	6.98	8.73	10.47	12.22	13.96	15.71	17.45
30	2.62	5.24	7.85	10.47	13.09	15.71	18.33	20.94	23.56	26.18
2	3.49	6.98	10.47	13.96	17.45	20.94	24.43	27.92	31.41	34.90
30	4.36	8.72	13.09	17.45	21.81	26.18	30.54	34.90	39.27	43.63
3	5.24	10.47	15.71	20.94	26.18	31.41	36.65	41.88	47.12	52.35
30	6.11	12.22	18.33	24.43	30.54	36.65	42.75	48.86	54.97	61.08
4	6.98	13.96	20.94	27.92	34.90	41.88	48.86	55.84	62.82	69.80
30	7.85	15.70	23.56	31.41	39.26	47.11	54.96	62.82	70.67	78.52
5	8.73	17.45	26.17	34.89	43.62	52.34	61.07	69.79	78.51	87.24
30	9.60	19.19	28.79	38.33	47.98	57.57	67.17	76.76	86.36	95.96
6	10.47	20.93	31.40	41.87	52.34	62.80	73.27	83.74	94.20	104.67
30	11.34	22.68	34.02	45.35	56.70	68.03	79.37	90.71	102.05	113.39
7	12.21	24.42	36.63	48.84	61.05	73.26	85.47	97.68	109.89	122.10
30	13.08	26.16	39.24	52.32	65.40	78.48	91.56	104.64	117.73	130.81
8	13.95	27.90	41.85	55.80	69.76	83.71	97.66	111.61	125.56	139.51
30	14.82	29.64	44.47	59.29	74.11	88.93	103.75	118.57	133.40	148.22
9	15.69	31.38	47.08	62.77	78.46	94.15	109.84	125.53	141.23	156.92
30	16.56	33.12	49.68	66.25	82.81	99.37	115.93	132.49	149.05	165.62
10	17.43	34.86	52.29	69.72	87.16	104.59	122.02	139.45	156.88	174.31
30	18.30	36.60	54.90	73.20	91.50	109.80	128.10	146.40	164.70	183.00
11	19.17	38.34	57.51	76.68	95.85	115.01	134.18	153.35	172.52	191.69
30	20.04	40.08	60.11	80.15	100.19	120.23	140.26	160.30	180.34	200.38
12	20.91	41.81	62.72	83.62	104.53	125.43	146.34	167.25	188.15	209.06
30	21.77	43.55	65.32	87.09	108.87	130.64	152.41	174.19	195.96	217.73
13	22.64	45.28	67.92	90.56	113.20	135.84	158.48	181.13	203.77	226.41
30	23.51	47.01	70.52	94.03	117.54	141.04	164.55	188.06	211.57	235.07
14	24.37	48.75	73.12	97.50	121.87	146.24	170.62	194.99	219.36	243.74
30	25.24	50.48	75.72	100.96	126.20	151.44	176.68	201.92	227.16	252.40
15	26.11	52.21	78.32	104.42	130.53	156.63	182.74	208.84	234.95	261.05
30	26.97	53.94	80.91	107.88	134.85	161.82	188.79	215.76	242.73	269.70
16	27.83	55.67	83.50	111.34	139.17	167.01	194.84	222.68	250.51	278.35
30	28.70	57.40	86.10	114.79	143.49	172.19	200.89	229.59	258.29	286.99
17	29.56	59.12	88.69	118.25	147.81	177.37	206.93	236.50	266.06	295.62
30	30.42	60.85	91.27	121.70	152.12	182.55	212.97	243.40	273.82	304.25
18	31.29	62.57	93.86	125.15	156.43	187.72	219.01	250.30	281.58	312.87
30	32.15	64.30	96.45	128.59	160.74	192.89	225.04	257.19	289.34	321.49
19	33.01	66.02	99.03	132.04	165.05	198.06	231.07	264.08	297.08	330.09
30	33.87	67.74	101.61	135.48	169.35	203.22	237.09	270.96	304.83	338.70
20	34.73	69.46	104.19	138.92	173.65	208.38	243.11	277.84	312.57	347.30
30	35.59	71.18	106.77	142.35	177.94	213.53	249.12	284.71	320.30	355.89
21	36.45	72.89	109.34	145.79	182.24	218.68	255.13	291.58	328.02	364.47
30	37.30	74.61	111.91	149.22	186.52	223.83	261.13	298.44	335.74	373.05
22	38.16	76.32	114.49	152.65	190.81	228.97	267.13	305.29	343.46	381.62
30	39.02	78.04	117.05	156.07	195.09	234.11	273.13	312.14	351.16	390.18
23	39.87	79.75	119.62	159.49	199.37	239.24	279.12	318.99	358.86	398.74
30	40.73	81.46	122.19	162.91	203.64	244.37	285.10	325.83	366.56	407.28
24	41.58	83.16	124.75	166.33	207.91	249.49	291.08	332.66	374.24	415.82
30	42.44	84.87	127.31	169.74	212.18	254.61	297.05	339.48	381.92	424.36
25	43.29	86.58	129.86	173.15	216.44	259.73	303.02	346.30	389.59	432.88
30	44.14	88.28	132.42	176.56	220.70	264.84	308.98	353.12	397.26	441.39
26	44.99	89.98	134.97	179.96	224.95	269.94	314.93	359.92	404.91	449.90
30	45.84	91.68	137.52	183.36	229.20	275.04	320.88	366.72	412.56	458.40
27	46.69	93.38	140.07	186.76	233.45	280.14	326.82	373.51	420.20	466.89
30	47.54	95.07	142.61	190.15	237.69	285.22	332.76	380.30	427.83	475.37
28	48.38	96.77	145.15	193.54	241.92	290.31	338.69	387.08	435.46	483.84
30	49.23	98.46	147.69	196.92	246.15	295.38	344.62	393.85	443.08	492.31
29	50.08	100.15	150.23	200.30	250.38	300.46	350.53	400.61	450.68	500.76
30	50.92	101.84	152.76	203.68	254.60	305.52	356.44	407.36	458.28	509.20
30	51.76	103.53	155.29	207.06	258.82	310.59	362.35	414.11	465.87	517.64

Degree of Curve.	1 Station.	2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
0° 10'	.036	.145	.327	.582	.909	1.309
20	.073	.291	.654	1.164	1.818	2.618
30	.109	.436	.982	1.745	2.727	3.926
40	.145	.582	1.309	2.327	3.636	5.235
50	.182	.727	1.636	2.909	4.545	6.544
1 10	.218	.873	1.963	3.490	5.453	7.852
20	.255	1.018	2.291	4.072	6.362	9.160
30	.291	1.164	2.618	4.654	7.270	10.468
40	.327	1.309	2.945	5.235	8.179	11.775
50	.364	1.454	3.272	5.816	9.087	13.082
2 10	.400	1.600	3.599	6.398	9.994	14.389
20	.436	1.745	3.926	6.979	10.902	15.694
30	.473	1.891	4.253	7.560	11.809	17.000
40	.509	2.036	4.580	8.141	12.716	18.304
50	.545	2.181	4.907	8.722	13.623	19.608
3 10	.582	2.327	5.234	9.303	14.529	20.912
20	.618	2.472	5.561	9.883	15.435	22.214
30	.654	2.618	5.888	10.464	16.341	23.516
40	.691	2.763	6.215	11.044	17.246	24.817
50	.727	2.908	6.542	11.624	18.151	26.117
4 10	.763	3.054	6.868	12.204	19.055	27.416
20	.800	3.199	7.195	12.784	19.959	28.714
30	.836	3.345	7.522	13.363	20.863	30.012
40	.872	3.490	7.848	13.943	21.766	31.308
50	.909	3.635	8.175	14.522	22.668	32.603
5 10	.945	3.781	8.501	15.101	23.570	33.896
20	.982	3.926	8.828	15.680	24.471	35.189
30	1.018	4.071	9.154	16.258	25.372	36.480
40	1.054	4.217	9.480	16.837	26.272	37.770
50	1.091	4.362	9.807	17.415	27.171	39.059
6 10	1.127	4.507	10.133	17.992	28.070	40.346
20	1.164	4.653	10.459	18.570	28.968	41.631
30	1.200	4.798	10.785	19.147	29.866	42.916
40	1.237	4.943	11.111	19.724	30.762	44.198
50	1.273	5.088	11.436	20.301	31.658	45.479
7 10	1.309	5.234	11.762	20.877	32.553	46.759
20	1.346	5.379	12.088	21.453	33.448	48.037
30	1.382	5.524	12.413	22.029	34.341	49.313
40	1.418	5.669	12.739	22.604	35.234	50.587
50	1.455	5.814	13.064	23.179	36.126	51.860
8 10	1.491	5.960	13.389	23.754	37.017	53.130
20	1.528	6.105	13.715	24.328	37.907	54.399
30	1.564	6.250	14.040	24.902	38.796	55.666
40	1.600	6.395	14.365	25.476	39.684	56.931
50	1.637	6.540	14.689	26.049	40.571	58.193
9 10	1.673	6.685	15.014	26.622	41.458	59.454
20	1.710	6.831	15.339	27.195	42.343	60.712
30	1.746	6.976	15.663	27.767	43.227	61.969
40	1.782	7.121	15.988	28.338	44.110	63.223
50	1.819	7.266	16.312	28.910	44.992	64.475
10 10	1.855	7.411	16.636	29.481	45.873	65.724
20	1.892	7.556	16.960	30.051	46.753	66.972
30	1.928	7.701	17.284	30.621	47.632	68.216
40	1.965	7.846	17.608	31.190	48.510	69.459
50	2.001	7.991	17.932	31.759	49.386	70.699
11 10	2.037	8.136	18.255	32.328	50.261	71.936
20	2.074	8.281	18.578	32.896	51.135	73.171
30	2.110	8.426	18.902	33.464	52.008	74.403
40	2.147	8.571	19.225	34.031	52.880	75.632
50	2.183	8.716	19.548	34.597	53.750	76.859

Degree of Curve.	7 Stations.	8 Stations.	9 Stations.	10 Stations.	11 Stations.	12 Stations.
0° 10'	1.782	2.327	2.945	3.636	4.400	5.236
20	3.563	4.654	5.890	7.272	8.799	10.471
30	5.345	6.981	8.835	10.907	13.197	15.704
40	7.126	9.307	11.778	14.540	17.593	20.986
50	8.907	11.632	14.721	18.173	21.987	26.164
1	10.687	13.957	17.663	21.803	26.378	31.388
10	12.467	16.281	20.603	25.431	30.766	36.607
20	14.246	18.604	23.541	29.057	35.150	41.821
30	16.024	20.925	26.477	32.679	39.530	47.028
40	17.802	23.246	29.411	36.298	43.905	52.229
50	19.579	25.564	32.343	39.914	48.274	57.422
2	21.355	27.881	35.272	43.525	52.637	62.606
10	23.130	30.197	38.198	47.131	56.993	67.780
20	24.903	32.510	41.121	50.733	61.343	72.945
30	26.676	34.821	44.040	54.330	65.684	78.098
40	28.447	37.130	46.956	57.921	70.018	83.240
50	30.216	39.436	49.868	61.506	74.342	88.370
3	31.984	41.740	52.776	65.084	78.657	93.486
10	33.751	44.041	55.679	68.656	82.963	98.588
20	35.516	46.339	58.577	72.221	87.258	103.675
30	37.279	48.634	61.471	75.778	91.542	108.747
40	39.040	50.926	64.360	79.328	95.814	113.803
50	40.800	53.215	67.243	82.869	100.075	118.841
4	42.557	55.500	70.121	86.402	104.323	123.862
10	44.312	57.781	72.992	89.925	108.558	128.864
20	46.065	60.059	75.858	93.440	112.779	133.847
30	47.816	62.333	78.717	96.945	116.986	138.810
40	49.564	64.602	81.570	100.439	121.178	143.753
50	51.310	66.868	84.416	103.924	125.356	148.674
5	53.053	69.129	87.255	107.397	129.517	153.572
10	54.794	71.386	90.087	110.860	133.663	158.448
20	56.532	73.638	92.911	114.311	137.791	163.300
30	58.267	75.885	95.728	117.751	141.903	168.128
40	59.999	78.127	98.536	121.178	145.997	172.931
50	61.729	80.364	101.337	124.593	150.072	177.708
6	63.455	82.596	104.129	127.995	154.129	182.459
10	65.178	84.822	106.912	131.384	158.166	187.182
20	66.898	87.043	109.686	134.759	162.184	191.878
30	68.615	89.258	112.452	138.120	166.182	196.545
40	70.328	91.468	115.208	141.468	170.159	201.183
50	72.037	93.671	117.954	144.800	174.114	205.792
7	73.744	95.868	120.691	148.118	178.048	210.370
10	75.446	98.059	123.417	151.421	181.960	214.916
20	77.145	100.244	126.134	154.708	185.850	219.431
30	78.840	102.422	128.840	157.979	189.716	223.914
40	80.531	104.594	131.535	161.234	193.559	228.363
50	82.218	106.758	134.219	164.473	197.377	232.779
8	83.901	108.916	136.893	167.695	201.171	237.160
10	85.580	111.067	139.555	170.899	204.941	241.507
20	87.254	113.210	142.205	174.086	208.685	245.818
30	88.924	115.346	144.844	177.255	212.403	250.093
40	90.590	117.475	147.470	180.407	216.095	254.331
50	92.252	119.596	150.085	183.539	219.760	258.531
9	93.909	121.709	152.687	186.653	223.398	262.694
10	95.561	123.814	155.277	189.748	227.008	266.818
20	97.208	125.911	157.854	192.824	230.591	270.904
30	98.851	128.000	160.417	195.880	234.145	274.949
40	100.489	130.081	162.968	198.916	237.670	278.955
50	102.122	132.153	165.505	201.932	241.167	282.919
10	103.750	134.217	168.029	204.928	244.633	286.848

Degree of Curve.	1 Station.	2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
10° 10'	2.219	8.860	19.870	35.164	54.619	78.083
20	2.256	9.005	20.193	35.729	55.486	79.305
30	2.293	9.150	20.516	36.294	56.353	80.523
40	2.329	9.295	20.838	36.859	57.218	81.739
50	2.365	9.440	21.160	37.423	58.081	82.951
11	2.402	9.585	21.483	37.986	58.943	84.161
10	2.438	9.729	21.804	38.549	59.804	85.368
20	2.475	9.874	22.126	39.111	60.663	86.571
30	2.511	10.019	22.448	39.673	61.521	87.772
40	2.547	10.164	22.769	40.234	62.377	88.969
50	2.584	10.308	23.090	40.795	63.232	90.164
12	2.620	10.453	23.412	41.355	64.085	91.355
10	2.657	10.597	23.732	41.914	64.937	92.542
20	2.693	10.742	24.053	42.473	65.787	93.727
30	2.730	10.887	24.374	43.031	66.636	94.908
40	2.766	11.031	24.694	43.588	67.482	96.086
50	2.803	11.176	25.014	44.145	68.328	97.260
13	2.839	11.320	25.334	44.701	69.171	98.431
10	2.876	11.465	25.654	45.256	70.012	99.598
20	2.912	11.609	25.974	45.811	70.854	100.762
30	2.949	11.754	26.293	46.365	71.692	101.922
40	2.985	11.898	26.612	46.919	72.529	103.079
50	3.022	12.043	26.931	47.472	73.364	104.232
14	3.058	12.187	27.250	48.024	74.197	105.381
10	3.095	12.331	27.569	48.575	75.029	106.527
20	3.131	12.476	27.887	49.126	75.859	107.669
30	3.168	12.620	28.206	49.676	76.687	108.807
40	3.204	12.764	28.524	50.225	77.513	109.941
50	3.241	12.908	28.841	50.773	78.337	111.071
15	3.277	13.053	29.159	51.321	79.159	112.197
10	3.314	13.197	29.476	51.868	79.979	113.319
20	3.350	13.341	29.794	52.414	80.798	114.438
30	3.387	13.485	30.111	52.959	81.614	115.552
40	3.423	13.629	30.427	53.504	82.429	116.662
50	3.460	13.773	30.744	54.048	83.241	117.768
16	3.496	13.917	31.060	54.591	84.052	118.870
10	3.533	14.061	31.376	55.133	84.861	119.967
20	3.569	14.205	31.692	55.675	85.667	121.061
30	3.606	14.349	32.008	56.215	86.471	122.150
40	3.643	14.493	32.323	56.755	87.274	123.235
50	3.679	14.637	32.638	57.294	88.074	124.315
17	3.716	14.781	32.953	57.832	88.872	125.391
10	3.752	14.925	33.267	58.369	89.668	126.463
20	3.789	15.069	33.582	58.906	90.462	127.530
30	3.825	15.212	33.896	59.441	91.254	128.593
40	3.862	15.356	34.210	59.976	92.043	129.651
50	3.899	15.500	34.523	60.510	92.830	130.704
18	3.935	15.643	34.837	61.042	93.616	131.753
10	3.972	15.787	35.150	61.574	94.398	132.797
20	4.008	15.931	35.463	62.106	95.179	133.837
30	4.045	16.074	35.775	62.636	95.957	134.872
40	4.081	16.218	36.088	63.165	96.733	135.902
50	4.118	16.361	36.400	63.693	97.506	136.928
19	4.155	16.505	36.712	64.221	98.278	137.948
10	4.191	16.648	37.023	64.747	99.047	138.964
20	4.228	16.792	37.334	65.273	99.813	139.975
30	4.265	16.935	37.645	65.797	100.577	140.981
40	4.301	17.078	37.956	66.321	101.339	141.982
50	4.338	17.222	38.266	66.843	102.098	142.978
20	4.374	17.365	38.576	67.365	102.855	143.969

Degree of Curve.	1 Station.	2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
21°	4.594	18.224	40.431	70.473	107.344	149.809
22	4.814	19.081	42.275	73.545	111.741	155.460
23	5.035	19.937	44.108	76.577	116.042	160.917
24	5.255	20.791	45.929	79.570	120.243	166.172
25	5.476	21.644	47.738	82.520	124.342	171.221
26	5.697	22.495	49.534	85.427	128.335	176.058
27	5.918	23.345	51.317	88.289	132.219	180.677
28	6.139	24.192	53.086	91.105	135.990	185.075
29	6.360	25.038	54.842	93.873	139.647	189.245
30	6.583	25.882	56.583	96.593	143.185	193.185
31°	6.805	26.724	58.309	99.261	146.603	
32	7.027	27.564	60.019	101.878	149.898	
33	7.250	28.402	61.714	104.442	153.068	
34	7.473	29.237	63.392	106.952	156.110	
35	7.696	30.071	65.053	109.406	159.023	
36	7.919	30.902	66.698	111.803	161.803	
37	8.143	31.730	68.325	114.143		
38	8.367	32.557	69.933	116.424		
39	8.592	33.381	71.524	118.645		
40	8.816	34.202	73.095	120.805		
41°	9.041	35.021	74.647	122.902		
42	9.267	35.837	76.180	124.937		
43	9.493	36.650	77.693	126.909		
44	9.719	37.461	79.185	128.815		
45	9.946	38.268	80.656	130.656		
46	10.173	39.073	82.107			
47	10.400	39.875	83.535			
48	10.628	40.674	84.942			
49	10.856	41.469	86.327			
50°	11.085	42.262	87.689			

24 TABLE VII.—CORRECTIONS FOR SUBCHORD LENGTHS

D	NOMINAL LENGTHS OF SUBCHORDS IN FEET										
	<i>m</i> *	5 .050	10 .099	15 .147	20 .192	25 .234	30 .273	35 .307	40 .336	45 .358	50 .374
4°	.020	0	0	0	0	0	0.01	0.01	0.01	0.01	0.01
5°	.032	0	0	0	0.01	0.01	.01	.01	.01	.01	.01
6°	.046	0	0	0.01	.01	.01	.01	.01	.02	.02	.02
7°	.062	0	0.01	.01	.01	.01	.02	.02	.02	.02	.02
8°	.081	0	.01	.01	.02	.02	.02	.02	.03	.03	.03
9°	.103	0.01	.01	.02	.02	.02	.03	.03	.03	.04	.04
10°	.127	.01	.01	.02	.02	.03	.03	.04	.04	.05	.05
11°	.154	.01	.02	.02	.03	.04	.04	.05	.05	.06	.06
12°	.183	.01	.02	.03	.04	.04	.05	.06	.06	.07	.07
13°	.215	.01	.02	.03	.04	.05	.06	.07	.07	.08	.08
14°	.249	.01	.02	.04	.05	.06	.07	.08	.08	.09	.09
15°	.286	.01	.03	.04	.05	.07	.08	.09	.10	.10	.11
16°	.326	.02	.03	.05	.06	.08	.09	.10	.11	.12	.12
17°	.368	.02	.04	.05	.07	.09	.10	.11	.12	.13	.14
18°	.412	.02	.04	.06	.08	.10	.11	.13	.14	.15	.15
19°	.460	.02	.05	.07	.09	.11	.13	.14	.15	.16	.17
20°	.510	.03	.05	.07	.10	.12	.14	.16	.17	.18	.19
21°	.562	.03	.06	.08	.11	.13	.15	.17	.19	.20	.21
22°	.617	.03	.06	.09	.12	.14	.17	.19	.21	.22	.23
23°	.675	.03	.07	.10	.13	.16	.18	.21	.23	.24	.25
24°	.735	.04	.07	.11	.14	.17	.20	.23	.25	.26	.27
25°	.798	.04	.08	.12	.15	.19	.22	.24	.27	.29	.30
26°	.863	.04	.09	.13	.17	.20	.24	.26	.29	.31	.32
27°	.931	.05	.09	.14	.18	.22	.25	.29	.31	.33	.35
28°	1.002	.05	.10	.15	.19	.23	.27	.31	.34	.36	.37
29°	1.075	.05	.11	.16	.21	.25	.29	.33	.36	.38	.40
30°	1.152	.06	.11	.17	.22	.27	.31	.35	.39	.41	.43
31°	1.230	.06	.12	.18	.24	.29	.34	.38	.41	.44	.46
32°	1.312	.07	.13	.19	.25	.31	.36	.40	.44	.47	.49
33°	1.396	.07	.14	.21	.27	.33	.38	.43	.47	.50	.52
34°	1.482	.07	.15	.22	.28	.35	.40	.45	.50	.53	.55
35°	1.572	.08	.16	.23	.30	.37	.43	.48	.53	.56	.59
36°	1.664	.08	.16	.24	.32	.39	.45	.51	.56	.60	.62
37°	1.759	.09	.17	.26	.34	.41	.48	.54	.59	.63	.66
38°	1.857	.09	.18	.27	.36	.43	.51	.57	.62	.66	.69
39°	1.957	.10	.19	.29	.38	.46	.53	.60	.66	.70	.73
40°	2.060	.10	.20	.30	.40	.48	.56	.63	.69	.74	.77
41°	2.166	.11	.21	.32	.42	.51	.59	.66	.73	.78	.81
42°	2.275	.11	.23	.33	.44	.53	.62	.70	.76	.81	.85
43°	2.386	.12	.24	.35	.46	.56	.65	.73	.80	.85	.89
44°	2.500	.12	.25	.37	.48	.58	.68	.77	.84	.90	.94
45°	2.617	.13	.26	.38	.50	.61	.71	.80	.88	.94	.98
46°	2.737	.14	.27	.40	.53	.64	.75	.84	.92	.98	1.02
47°	2.860	.14	.28	.42	.55	.67	.78	.88	.96	1.02	1.07
48°	2.985	.15	.30	.44	.57	.70	.81	.92	1.00	1.07	1.12
49°	3.114	.16	.31	.46	.60	.73	.85	.96	1.05	1.11	1.16
50°	3.245	.16	.32	.48	.62	.76	.89	1.00	1.09	1.16	1.21

* Multiply number in column *m* by number in line *m* to find correction exact to three or four places.

TABLE VII.—CORRECTIONS FOR SUBCHORD LENGTHS 25

D	NOMINAL LENGTHS OF SUBCHORDS IN FEET									
	<i>m</i> *	55 .383	60 .383	65 .374	70 .356	75 .327	80 .287	85 .235	90 .169	95 .092
4°	.020	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0
5°	.032	.01	.01	.01	.01	.01	.01	0.01	0.01	0
6°	.046	.02	.02	.02	.02	.02	.01	.01	.01	0
7°	.062	.02	.02	.02	.02	.02	.02	.01	.01	0.01
8°	.081	.03	.03	.03	.03	.03	.02	.02	.01	.01
9°	.103	.04	.04	.04	.04	.03	.03	.02	.02	.01
10°	.127	.05	.05	.05	.05	.04	.04	.03	.02	.01
11°	.154	.06	.06	.06	.05	.05	.04	.04	.03	.01
12°	.183	.07	.07	.07	.07	.06	.05	.04	.03	.02
13°	.215	.08	.08	.08	.08	.07	.06	.05	.04	.02
14°	.249	.10	.10	.09	.09	.08	.07	.06	.04	.02
15°	.286	.11	.11	.11	.10	.09	.08	.07	.05	.03
16°	.326	.12	.13	.12	.12	.11	.09	.08	.06	.03
17°	.368	.14	.14	.14	.13	.12	.11	.09	.06	.03
18°	.412	.16	.16	.15	.15	.14	.12	.10	.07	.04
19°	.460	.18	.18	.17	.16	.15	.13	.11	.08	.04
20°	.510	.20	.20	.19	.18	.17	.15	.12	.09	.05
21°	.562	.22	.22	.21	.20	.18	.16	.13	.09	.05
22°	.617	.24	.24	.23	.22	.20	.18	.14	.10	.06
23°	.675	.26	.26	.25	.24	.22	.19	.16	.11	.06
24°	.735	.28	.28	.27	.26	.24	.21	.17	.12	.07
25°	.798	.31	.31	.30	.28	.26	.23	.19	.13	.07
26°	.863	.33	.33	.32	.31	.28	.25	.20	.15	.08
27°	.931	.36	.36	.35	.33	.30	.27	.22	.16	.09
28°	1.002	.38	.38	.37	.36	.33	.29	.24	.17	.09
29°	1.075	.41	.41	.40	.38	.35	.31	.25	.18	.10
30°	1.152	.44	.44	.43	.41	.38	.33	.27	.19	.11
31°	1.230	.47	.47	.46	.44	.40	.35	.29	.21	.11
32°	1.312	.50	.50	.49	.47	.43	.38	.31	.22	.12
33°	1.396	.53	.53	.52	.50	.46	.40	.33	.24	.13
34°	1.482	.57	.57	.55	.53	.48	.43	.35	.25	.14
35°	1.572	.60	.60	.59	.56	.51	.45	.37	.27	.14
36°	1.664	.64	.64	.62	.59	.54	.48	.39	.28	.15
37°	1.759	.67	.67	.66	.63	.58	.50	.41	.30	.16
38°	1.857	.71	.71	.69	.66	.61	.53	.44	.31	.17
39°	1.957	.75	.75	.73	.70	.64	.56	.46	.33	.18
40°	2.060	.79	.79	.77	.73	.67	.59	.48	.35	.19
41°	2.166	.83	.83	.81	.77	.71	.62	.51	.37	.20
42°	2.275	.87	.87	.85	.81	.74	.65	.53	.38	.21
43°	2.386	.91	.91	.89	.85	.78	.68	.56	.40	.22
44°	2.500	.96	.96	.94	.89	.82	.72	.59	.42	.23
45°	2.617	1.00	1.00	.98	.93	.86	.75	.61	.44	.24
46°	2.737	1.05	1.05	1.02	.97	.89	.79	.64	.46	.25
47°	2.860	1.10	1.10	1.07	1.02	.94	.82	.67	.48	.26
48°	2.985	1.14	1.14	1.12	1.06	.98	.86	.70	.50	.27
49°	3.114	1.19	1.19	1.16	1.11	1.02	.89	.73	.53	.29
50°	3.245	1.24	1.24	1.21	1.16	1.06	.93	.76	.55	.30

* Multiply number in column *m* by number in line *m* to find correction exact to three or four places.

D	LENGTH OF RAIL-CHORD.												D
	60	45	33	32	30	28	26	24	22	20	18	16	
1°	.078	.043	.024	.022	.020	.017	.015	.013	.011	.009	.007	.006	1°
2	.157	.088	.047	.045	.039	.034	.030	.025	.021	.017	.014	.011	2
3	.235	.132	.070	.067	.059	.051	.044	.038	.032	.026	.021	.017	3
4	.314	.176	.094	.089	.079	.068	.059	.050	.042	.035	.028	.022	4
5	.391	.221	.118	.112	.098	.086	.074	.063	.053	.044	.035	.028	5
6	.471	.264	.143	.134	.118	.103	.088	.075	.063	.052	.042	.034	6
7	.550	.309	.166	.156	.137	.120	.103	.088	.074	.061	.049	.039	7
8	.628	.353	.190	.179	.157	.137	.118	.100	.084	.070	.057	.045	8
9	.706	.397	.214	.201	.177	.154	.133	.113	.095	.078	.064	.050	9
10	.785	.441	.237	.223	.196	.171	.147	.126	.105	.087	.071	.056	10
11	.863	.485	.261	.245	.216	.188	.162	.138	.116	.096	.078	.061	11
12	.942	.529	.285	.268	.235	.205	.177	.151	.127	.105	.085	.067	12
14	1.098	.617	.332	.312	.274	.238	.206	.175	.147	.122	.099	.078	14
16	1.255	.705	.379	.356	.313	.273	.235	.200	.168	.139	.113	.089	16
18	1.411	.793	.426	.400	.352	.307	.264	.225	.189	.156	.127	.100	18
20	1.567	.880	.473	.445	.391	.340	.293	.250	.210	.174	.141	.111	20
24	1.878	1.055	.567	.531	.467	.407	.351	.299	.251	.207	.168	.133	24
28	2.189	1.228	.660	.618	.543	.473	.408	.347	.292	.241	.195	.154	28
32	2.498	1.401	.752	.705	.619	.539	.465	.396	.333	.275	.223	.176	32
36	2.805	1.572	.844	.791	.696	.606	.522	.445	.373	.309	.250	.197	36
40	3.111	1.742	.934	.878	.772	.672	.579	.493	.414	.342	.277	.219	40
45	3.491	1.952	1.046	.983	.863	.752	.648	.552	.463	.383	.305	.245	45
50	3.867	2.159	1.156	1.087	.955	.831	.716	.610	.512	.423	.343	.271	50

TABLE IX.—DIFFERENCE IN ELEVATION OF RAILS ON CURVES

[illegible]

ELEVATION OF OUTER RAIL IN INCHES

[illegible]

28. TABLE X.—INCHES IN DECIMALS OF A FOOT

In.	0	1	2	3	4	5	6	7	8	9	10	11	In.
0	Foot	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167	0
1-32		.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	1-32
1-16		.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	1-16
3-32		.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	3-32
1-8		.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	1-8
5-32		.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	5-32
3-16		.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	3-16
7-32		.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	7-32
1-4		.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	1-4
9-32		.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	9-32
5-16		.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	5-16
11-32		.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	11-32
3-8		.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	3-8
13-32		.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	13-32
7-16		.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	7-16
15-32		.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	15-32
1-2		.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	1-2
17-32		.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	17-32
9-16		.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	9-16
19-32		.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	19-32
5-8		.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	5-8
21-32		.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	21-32
11-16		.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	11-16
23-32		.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	23-32
3-4		.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	3-4
25-32		.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	25-32
13-16		.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	13-16
27-32		.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	27-32
7-8		.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	7-8
29-32		.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	29-32
15-16		.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	15-16
31-32		.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	31-32
	0	1	2	3	4	5	6	7	8	9	10	11	

Defl. Angle 20 m. Chord.	Radius in Meters.	Log. of Radius.	Mid. Ord.	Tang. Off.	Degree of Equiv. U. S. Curve.	Defl. Angle 20 m. Chord.
0° 10'	3437.75	3.536274	.015	.058	0° 30'	0° 10'
20	1718.89	3.235246	.029	.116	1 01	20
30	1145.93	3.059158	.044	.175	1 31	30
40	859.46	2.934224	.058	.233	2 02	40
50	687.57	2.837319	.073	.291	2 32	50
1 00	572.99	2.758145	.087	.349	3 03	1 00
10	491.14	2.691206	.102	.407	3 33	10
20	429.76	2.633223	.116	.465	4 04	20
30	382.02	2.582081	.131	.524	4 34	30
40	343.82	2.536335	.145	.582	5 05	40
50	312.58	2.494955	.160	.640	5 35	50
2 00	286.54	2.457181	.175	.698	6 06	2 00
10	264.51	2.422434	.189	.756	6 36	10
20	245.62	2.390266	.204	.814	7 07	20
30	229.26	2.360320	.218	.872	7 37	30
40	214.94	2.332311	.233	.931	8 08	40
50	202.30	2.306002	.247	.989	8 38	50
3 00	191.07	2.281200	.262	1.047	9 09	3 00
10	181.03	2.257741	.276	1.105	9 40	10
20	171.98	2.235489	.291	1.163	10 10	20
30	163.80	2.214325	.306	1.221	10 41	30
40	156.37	2.194148	.320	1.279	11 11	40
50	149.58	2.174870	.335	1.337	11 42	50
4 00	143.36	2.156416	.349	1.395	12 12	4 00
10	137.63	2.138717	.364	1.453	12 43	10
20	132.35	2.121715	.378	1.511	13 13	20
30	127.45	2.105357	.393	1.569	13 44	30
40	122.91	2.089596	.407	1.627	14 15	40
50	118.68	2.074391	.422	1.685	14 45	50
5 00	114.737	2.059704	.437	1.743	15 16	5 00
10	111.045	2.045501	.451	1.801	15 47	10
20	107.585	2.031751	.466	1.859	16 17	20
30	104.334	2.018427	.480	1.917	16 48	30
40	101.275	2.005503	.495	1.975	17 19	40
50	98.391	1.992956	.509	2.033	17 49	50
6 00	95.668	1.980765	.524	2.091	18 20	6 00
10	93.092	1.968911	.539	2.148	18 51	10
20	90.652	1.957375	.553	2.206	19 21	20
30	88.337	1.946141	.568	2.264	19 52	30
40	86.138	1.935194	.582	2.322	20 23	40
50	84.047	1.924520	.597	2.380	20 54	50
7 00	82.055	1.914105	.612	2.437	21 24	7 00
10	80.156	1.903938	.626	2.495	21 55	10
20	78.344	1.894008	.641	2.553	22 26	20
30	76.613	1.884302	.655	2.611	22 57	30
40	74.957	1.874813	.670	2.668	23 28	40
50	73.372	1.865530	.685	2.726	23 59	50
8 00	71.853	1.856445	.699	2.783	24 29	8 00
10	70.396	1.847549	.714	2.841	25 00	10
20	68.998	1.838836	.729	2.899	25 31	20
30	67.655	1.830298	.743	2.956	26 02	30
40	66.363	1.821928	.758	3.014	26 33	40
50	65.121	1.813720	.772	3.071	27 04	50
9 00	63.925	1.805668	.787	3.129	27 35	9 00
10	62.772	1.797766	.802	3.186	28 06	10
20	61.661	1.790008	.816	3.244	28 37	20
30	60.589	1.782391	.831	3.301	29 08	30
40	59.554	1.774908	.846	3.358	29 39	40
50	58.554	1.767556	.860	3.416	30 10	50
10° 00'	57.588	1.760330	.875	3.473	30 41	10° 00'

Sta. of 100'	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Sta. of 100'
0	0.000	0.023	0.046	0.069	0.092	0.115	0.138	0.161	0.184	0.207	0
1	0.230	0.252	0.275	0.298	0.321	0.344	0.367	0.390	0.413	0.436	1
2	0.459	0.482	0.505	0.528	0.551	0.574	0.597	0.620	0.643	0.666	2
3	0.689	0.712	0.735	0.757	0.780	0.803	0.826	0.849	0.872	0.895	3
4	0.918	0.941	0.964	0.987	1.010	1.033	1.056	1.079	1.102	1.125	4
5	1.148	1.171	1.194	1.217	1.240	1.263	1.286	1.309	1.331	1.354	5
6	1.377	1.400	1.423	1.446	1.469	1.492	1.515	1.538	1.561	1.584	6
7	1.608	1.631	1.654	1.677	1.700	1.723	1.746	1.769	1.792	1.814	7
8	1.837	1.860	1.882	1.905	1.928	1.951	1.974	1.997	2.020	2.043	8
9	2.066	2.089	2.112	2.135	2.158	2.181	2.204	2.227	2.250	2.273	9
10	2.296	2.319	2.342	2.365	2.388	2.410	2.433	2.456	2.479	2.502	10
11	2.525	2.548	2.571	2.594	2.617	2.640	2.663	2.686	2.709	2.732	11
12	2.755	2.778	2.801	2.824	2.847	2.870	2.893	2.916	2.938	2.961	12
13	2.984	3.007	3.030	3.053	3.076	3.099	3.122	3.145	3.168	3.191	13
14	3.214	3.237	3.260	3.283	3.306	3.329	3.352	3.375	3.398	3.421	14
15	3.444	3.466	3.489	3.512	3.535	3.558	3.581	3.604	3.627	3.650	15
16	3.673	3.696	3.719	3.742	3.765	3.788	3.811	3.834	3.857	3.880	16
17	3.903	3.926	3.949	3.972	3.994	4.017	4.040	4.063	4.086	4.109	17
18	4.132	4.155	4.178	4.201	4.224	4.247	4.270	4.293	4.316	4.339	18
19	4.362	4.385	4.408	4.431	4.454	4.477	4.500	4.522	4.545	4.568	19
20	4.591	4.614	4.637	4.660	4.683	4.706	4.729	4.752	4.775	4.798	20
21	4.821	4.844	4.867	4.890	4.913	4.936	4.959	4.982	5.005	5.028	21
22	5.051	5.073	5.096	5.119	5.142	5.165	5.188	5.211	5.234	5.257	22
23	5.280	5.303	5.326	5.349	5.372	5.395	5.418	5.441	5.464	5.487	23
24	5.510	5.533	5.556	5.579	5.601	5.624	5.647	5.670	5.693	5.716	24
25	5.739	5.762	5.785	5.808	5.831	5.854	5.877	5.900	5.923	5.946	25
26	5.969	5.992	6.015	6.038	6.061	6.084	6.107	6.129	6.152	6.175	26
27	6.198	6.221	6.244	6.267	6.290	6.313	6.336	6.359	6.382	6.405	27
28	6.428	6.451	6.474	6.497	6.520	6.543	6.566	6.589	6.612	6.635	28
29	6.657	6.680	6.703	6.726	6.749	6.772	6.795	6.818	6.841	6.864	29
30	6.887	6.910	6.933	6.956	6.979	7.002	7.025	7.048	7.071	7.094	30
31	7.117	7.140	7.163	7.185	7.208	7.231	7.254	7.277	7.300	7.323	31
32	7.346	7.369	7.392	7.415	7.438	7.461	7.484	7.507	7.530	7.553	32
33	7.576	7.599	7.622	7.645	7.668	7.691	7.714	7.736	7.759	7.782	33
34	7.805	7.828	7.851	7.874	7.897	7.920	7.943	7.966	7.989	8.012	34
35	8.035	8.058	8.081	8.104	8.127	8.150	8.173	8.196	8.219	8.242	35
36	8.264	8.287	8.310	8.333	8.356	8.379	8.402	8.425	8.448	8.471	36
37	8.494	8.517	8.540	8.563	8.586	8.609	8.632	8.655	8.678	8.701	37
38	8.724	8.747	8.770	8.792	8.815	8.838	8.861	8.884	8.907	8.930	38
39	8.953	8.976	8.999	9.022	9.045	9.068	9.091	9.114	9.137	9.160	39
40	9.183	9.206	9.229	9.252	9.275	9.298	9.320	9.343	9.366	9.389	40
41	9.412	9.435	9.458	9.481	9.504	9.527	9.550	9.573	9.596	9.619	41
42	9.642	9.665	9.688	9.711	9.734	9.757	9.780	9.803	9.826	9.848	42
43	9.871	9.894	9.917	9.940	9.963	9.986	10.009	10.032	10.055	10.078	43
44	10.101	10.124	10.147	10.170	10.193	10.216	10.239	10.262	10.285	10.308	44
45	10.331	10.354	10.377	10.399	10.422	10.445	10.468	10.491	10.514	10.537	45
46	10.560	10.583	10.606	10.629	10.652	10.675	10.698	10.721	10.744	10.767	46
47	10.790	10.813	10.836	10.859	10.882	10.905	10.927	10.950	10.973	10.996	47
48	11.019	11.042	11.065	11.088	11.111	11.134	11.157	11.180	11.203	11.226	48
49	11.249	11.272	11.295	11.318	11.341	11.364	11.387	11.410	11.433	11.455	49
50	11.478	11.501	11.524	11.547	11.570	11.593	11.616	11.639	11.662	11.685	50
51	11.708	11.731	11.754	11.777	11.800	11.823	11.846	11.869	11.892	11.915	51
52	11.938	11.961	11.983	12.006	12.029	12.052	12.075	12.098	12.121	12.144	52

TABLE XIII.—VELOCITY HEADS FOR VARIOUS SPEEDS

Speed in Miles per Hour.	VELOCITY HEADS IN FEET.									
	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03
1	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.13
2	0.14	0.16	0.17	0.19	0.20	0.22	0.24	0.26	0.28	0.30
3	0.32	0.34	0.36	0.39	0.41	0.43	0.46	0.49	0.51	0.54
4	0.57	0.60	0.63	0.66	0.69	0.72	0.75	0.78	0.82	0.85
5	0.89	0.92	0.96	1.00	1.04	1.07	1.11	1.15	1.19	1.24
6	1.28	1.32	1.36	1.41	1.45	1.50	1.55	1.59	1.64	1.69
7	1.74	1.79	1.84	1.89	1.94	2.00	2.05	2.10	2.16	2.22
8	2.27	2.33	2.39	2.45	2.50	2.56	2.63	2.69	2.75	2.81
9	2.88	2.94	3.00	3.07	3.14	3.20	3.27	3.34	3.41	3.48
10	3.55	3.62	3.69	3.77	3.84	3.91	3.99	4.06	4.14	4.22
11	4.30	4.37	4.45	4.53	4.61	4.69	4.78	4.86	4.94	5.03
12	5.11	5.20	5.28	5.37	5.46	5.55	5.64	5.73	5.82	5.91
13	6.00	6.09	6.19	6.28	6.37	6.47	6.57	6.66	6.76	6.86
14	6.96	7.06	7.16	7.26	7.36	7.46	7.57	7.67	7.78	7.88
15	7.99	8.09	8.20	8.31	8.42	8.53	8.64	8.75	8.86	8.97
16	9.09	9.20	9.32	9.43	9.55	9.66	9.78	9.89	10.02	10.14
17	10.26	10.38	10.50	10.62	10.75	10.87	11.00	11.12	11.25	11.37
18	11.50	11.63	11.76	11.89	12.02	12.15	12.28	12.41	12.55	12.68
19	12.82	12.95	13.09	13.22	13.36	13.50	13.64	13.78	13.92	14.06
20	14.20	14.34	14.49	14.63	14.77	14.92	15.06	15.21	15.36	15.51
21	15.66	15.80	15.96	16.11	16.26	16.41	16.56	16.72	16.87	17.03
22	17.18	17.34	17.50	17.65	17.81	17.97	18.13	18.29	18.45	18.62
23	18.78	18.94	19.11	19.27	19.44	19.60	19.77	19.94	20.11	20.28
24	20.45	20.62	20.79	20.96	21.14	21.31	21.48	21.66	21.83	22.01
25	22.19	22.37	22.54	22.72	22.90	23.08	23.27	23.45	23.63	23.81
26	24.00	24.18	24.37	24.55	24.74	24.93	25.12	25.31	25.50	25.69
27	25.88	26.07	26.26	26.46	26.65	26.85	27.04	27.24	27.44	27.63
28	27.83	28.03	28.23	28.43	28.63	28.83	29.04	29.24	29.45	29.65
29	29.86	30.06	30.27	30.48	30.68	30.89	31.10	31.31	31.53	31.74
30	31.95	32.16	32.38	32.59	32.81	33.02	33.24	33.46	33.68	33.90
31	34.12	34.34	34.56	34.78	35.00	35.22	35.45	35.67	35.90	36.13
32	36.35	36.58	36.81	37.04	37.27	37.50	37.73	37.96	38.19	38.43
33	38.66	38.89	39.13	39.37	39.60	39.84	40.08	40.32	40.56	40.80
34	41.04	41.28	41.52	41.77	42.01	42.25	42.50	42.75	42.99	43.24
35	43.49	43.74	43.99	44.24	44.49	44.74	44.99	45.24	45.50	45.75
36	46.01	46.26	46.52	46.78	47.04	47.29	47.55	47.81	48.08	48.34
37	48.60	48.86	49.13	49.39	49.66	49.92	50.19	50.46	50.72	50.99
38	51.26	51.53	51.80	52.07	52.35	52.62	52.89	53.17	53.44	53.72
39	54.00	54.27	54.55	54.83	55.11	55.39	55.67	55.95	56.23	56.52
40	56.80	57.08	57.37	57.66	57.94	58.23	58.52	58.81	59.09	59.38
41	59.68	59.97	60.26	60.55	60.85	61.14	61.43	61.73	62.03	62.32
42	62.62	62.92	63.22	63.52	63.82	64.12	64.42	64.73	65.03	65.33
43	65.64	65.95	66.25	66.56	66.87	67.17	67.48	67.79	68.10	68.42
44	68.73	69.04	69.35	69.67	69.98	70.30	70.62	70.93	71.25	71.57
45	71.89	72.21	72.53	72.85	73.17	73.49	73.82	74.14	74.47	74.79
46	75.12	75.44	75.77	76.10	76.43	76.76	77.09	77.42	77.75	78.09
47	78.42	78.75	79.09	79.42	79.76	80.10	80.43	80.77	81.11	81.45
48	81.79	82.13	82.48	82.82	83.16	83.50	83.85	84.19	84.54	84.89
49	85.24	85.58	85.93	86.28	86.63	86.98	87.34	87.69	88.04	88.40
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
50	88.75	92.34	95.99	99.72	103.52	107.39	111.33	115.34	119.42	123.58
60	127.80	132.10	136.46	140.90	145.41	149.99	154.64	159.36	164.15	169.02
70	173.95	178.96	184.03	189.18	194.40	199.69	205.05	210.48	215.98	221.56
80	227.20	232.92	238.70	244.56	250.49	256.49	262.56	268.70	274.91	281.20
90	287.55	293.98	300.47	307.04	313.68	320.39	327.17	334.02	340.94	347.94

Feet per Sta- tion.	Feet per Mile.	Inclina- tion.	Feet per Sta- tion.	Feet per Mile.	Inclina- tion.	Feet per Sta- tion.	Feet per Mile.	Inclina- tion.
		° ' "			° ' "			° ' "
.01	.528	21	.51	26.928	17 32	1.01	53.328	34 43
.02	1.056	41	.52	27.456	17 53	1.02	53.856	35 04
.03	1.584	1 02	.53	27.984	18 13	1.03	54.384	35 24
.04	2.112	1 23	.54	28.512	18 34	1.04	54.912	35 45
.05	2.640	1 43	.55	29.040	18 54	1.05	55.440	36 05
.06	3.168	2 04	.56	29.568	19 15	1.06	55.968	36 26
.07	3.696	2 24	.57	30.096	19 36	1.07	56.496	36 47
.08	4.224	2 45	.58	30.624	19 56	1.08	57.024	37 08
.09	4.752	3 06	.59	31.152	20 17	1.09	57.552	37 28
.10	5.280	3 26	.60	31.680	20 38	1.10	58.080	37 49
.11	5.808	3 47	.61	32.208	20 58	1.11	58.608	38 09
.12	6.336	4 08	.62	32.736	21 19	1.12	59.136	38 30
.13	6.864	4 28	.63	33.264	21 39	1.13	59.664	38 51
.14	7.392	4 49	.64	33.792	22 00	1.14	60.192	39 11
.15	7.920	5 09	.65	34.320	22 21	1.15	60.720	39 32
.16	8.448	5 30	.66	34.848	22 41	1.16	61.248	39 53
.17	8.976	5 51	.67	35.376	23 02	1.17	61.776	40 13
.18	9.504	6 11	.68	35.904	23 23	1.18	62.304	40 34
.19	10.032	6 32	.69	36.432	23 43	1.19	62.832	40 54
.20	10.560	6 53	.70	36.960	24 04	1.20	63.360	41 15
.21	11.088	7 13	.71	37.488	24 24	1.21	63.888	41 35
.22	11.616	7 34	.72	38.016	24 45	1.22	64.416	41 56
.23	12.144	7 54	.73	38.544	25 06	1.23	64.944	42 17
.24	12.672	8 15	.74	39.072	25 26	1.24	65.472	42 38
.25	13.200	8 36	.75	39.600	25 47	1.25	66.000	42 58
.26	13.728	8 56	.76	40.128	26 08	1.26	66.528	43 19
.27	14.256	9 17	.77	40.656	26 28	1.27	67.056	43 39
.28	14.784	9 38	.78	41.184	26 49	1.28	67.584	44 00
.29	15.312	9 58	.79	41.712	27 09	1.29	68.112	44 21
.30	15.840	10 19	.80	42.240	27 30	1.30	68.640	44 41
.31	16.368	10 39	.81	42.768	27 51	1.31	69.168	45 02
.32	16.896	11 00	.82	43.296	28 11	1.32	69.696	45 23
.33	17.424	11 21	.83	43.824	28 32	1.33	70.224	45 43
.34	17.952	11 41	.84	44.352	28 53	1.34	70.752	46 04
.35	18.480	12 02	.85	44.880	29 13	1.35	71.280	46 24
.36	19.008	12 23	.86	45.408	29 34	1.36	71.808	46 45
.37	19.536	12 43	.87	45.936	29 54	1.37	72.336	47 06
.38	20.064	13 04	.88	46.464	30 15	1.38	72.864	47 26
.39	20.592	13 24	.89	46.992	30 36	1.39	73.392	47 47
.40	21.120	13 45	.90	47.520	30 57	1.40	73.920	48 08
.41	21.648	14 06	.91	48.048	31 17	1.41	74.448	48 28
.42	22.176	14 26	.92	48.576	31 38	1.42	74.976	48 49
.43	22.704	14 47	.93	49.104	31 58	1.43	75.504	49 09
.44	23.232	15 08	.94	49.632	32 19	1.44	76.032	49 30
.45	23.760	15 28	.95	50.160	32 39	1.45	76.560	49 51
.46	24.288	15 49	.96	50.688	33 00	1.46	77.088	50 11
.47	24.816	16 09	.97	51.216	33 21	1.47	77.616	50 32
.48	25.344	16 30	.98	51.744	33 41	1.48	78.144	50 52
.49	25.872	16 51	.99	52.272	34 02	1.49	78.672	51 13
.50	26.400	17 11	1.00	52.800	34 23	1.50	79.200	51 34

Feet per Sta- tion.	Feet per Mile.	Inclina- tion.	Feet per Sta- tion.	Feet per Mile.	Inclina- tion.	Feet per Sta- tion.	Feet per Mile.	Inclina- tion.
		° ' "			° ' "			° ' "
1.51	79.728	51 54	2.05	108.240	1 10 28	5.10	269.280	2 55 10
1.52	80.256	52 15	2.10	110.880	1 12 11	5.20	274.560	2 58 36
1.53	80.784	52 36	2.15	113.520	1 13 54	5.30	279.840	3 02 01
1.54	81.312	52 56	2.20	116.160	1 15 37	5.40	285.120	3 05 27
1.55	81.840	53 17	2.25	118.800	1 17 20	5.50	290.400	3 08 53
1.56	82.368	53 37	2.30	121.440	1 19 03	5.60	295.680	3 12 19
1.57	82.896	53 58	2.35	124.080	1 20 46	5.70	300.960	3 15 44
1.58	83.424	54 19	2.40	126.720	1 22 29	5.80	306.240	3 19 10
1.59	83.952	54 39	2.45	129.360	1 24 12	5.90	311.520	3 22 36
1.60	84.480	55 00	2.50	132.000	1 25 56	6.00	316.800	3 26 01
1.61	85.008	55 21	2.55	134.640	1 27 39	6.10	322.080	3 29 27
1.62	85.536	55 41	2.60	137.280	1 29 22	6.20	327.360	3 32 52
1.63	86.064	56 02	2.65	139.920	1 31 05	6.30	332.640	3 36 18
1.64	86.592	56 22	2.70	142.560	1 32 48	6.40	337.920	3 39 43
1.65	87.120	56 43	2.75	145.200	1 34 31	6.50	343.200	3 43 08
1.66	87.648	57 04	2.80	147.840	1 36 14	6.60	348.480	3 46 34
1.67	88.176	57 24	2.85	150.480	1 37 57	6.70	353.760	3 49 59
1.68	88.704	57 45	2.90	153.120	1 39 40	6.80	359.040	3 53 24
1.69	89.232	58 06	2.95	155.760	1 41 23	6.90	364.320	3 56 50
1.70	89.760	58 26	3.00	158.400	1 43 06	7.00	369.600	4 00 15
1.71	90.288	58 47	3.05	161.040	1 44 49	7.10	374.880	4 03 40
1.72	90.816	59 07	3.10	163.680	1 46 32	7.20	380.160	4 07 06
1.73	91.344	59 28	3.15	166.320	1 48 15	7.30	385.440	4 10 31
1.74	91.872	59 49	3.20	168.960	1 49 58	7.40	390.720	4 13 56
1.75	92.400	1 00 09	3.25	171.600	1 51 41	7.50	396.000	4 17 21
1.76	92.928	1 00 30	3.30	174.240	1 53 24	7.60	401.280	4 20 46
1.77	93.456	1 00 51	3.35	176.880	1 55 07	7.70	406.560	4 24 11
1.78	93.984	1 01 11	3.40	179.520	1 56 50	7.80	411.840	4 27 36
1.79	94.512	1 01 32	3.45	182.160	1 58 33	7.90	417.120	4 31 01
1.80	95.040	1 01 52	3.50	184.800	2 00 16	8.00	422.400	4 34 26
1.81	95.568	1 02 13	3.55	187.440	2 01 59	8.10	427.680	4 37 51
1.82	96.096	1 02 34	3.60	190.080	2 03 42	8.20	432.960	4 41 16
1.83	96.624	1 02 54	3.65	192.720	2 05 25	8.30	438.240	4 44 41
1.84	97.152	1 03 15	3.70	195.360	2 07 08	8.40	443.520	4 48 06
1.85	97.680	1 03 35	3.75	198.000	2 08 51	8.50	448.800	4 51 30
1.86	98.208	1 03 56	3.80	200.640	2 10 34	8.60	454.080	4 54 55
1.87	98.736	1 04 17	3.85	203.280	2 12 17	8.70	459.360	4 58 20
1.88	99.264	1 04 37	3.90	205.920	2 14 00	8.80	464.640	5 01 44
1.89	99.792	1 04 58	3.95	208.560	2 15 43	8.90	469.920	5 05 10
1.90	100.320	1 05 19	4.00	211.200	2 17 26	9.00	475.200	5 08 34
1.91	100.848	1 05 39	4.10	216.480	2 20 52	9.10	480.480	5 11 59
1.92	101.376	1 06 00	4.20	221.760	2 24 18	9.20	485.760	5 15 23
1.93	101.904	1 06 20	4.30	227.040	2 27 44	9.30	491.040	5 18 48
1.94	102.432	1 06 41	4.40	232.320	2 31 10	9.40	496.320	5 22 12
1.95	102.960	1 07 02	4.50	237.600	2 34 36	9.50	501.600	5 25 37
1.96	103.488	1 07 22	4.60	242.880	2 38 01	9.60	506.880	5 29 01
1.97	104.016	1 07 43	4.70	248.160	2 41 27	9.70	512.160	5 32 25
1.98	104.544	1 08 04	4.80	253.440	2 44 53	9.80	517.440	5 35 50
1.99	105.072	1 08 24	4.90	258.720	2 48 19	9.90	522.720	5 39 14
2.00	105.600	1 08 45	5.00	264.000	2 51 45	10.00	528.000	5 42 38

Barom- eter. Inches = <i>h</i> .	0.00	0.02	0.04	0.06	0.08	Diff. per .002 in.
19 .0	16832	16860	16888	16915	16943	2.8
.1	16970	16997	17025	17052	17080	2.8
.2	17107	17134	17162	17189	17216	2.7
.3	17243	17270	17298	17325	17352	2.7
.4	17379	17406	17433	17460	17487	2.7
.5	17514	17540	17567	17594	17621	2.7
.6	17648	17674	17701	17728	17755	2.7
.7	17781	17808	17834	17861	17887	2.7
.8	17914	17940	17967	17993	18020	2.7
.9	18046	18072	18099	18125	18151	2.6
20 .0	18178	18204	18230	18256	18282	2.6
.1	18308	18334	18360	18386	18413	2.6
.2	18438	18464	18490	18516	18542	2.6
.3	18568	18594	18620	18645	18671	2.6
.4	18697	18723	18748	18774	18799	2.6
.5	18825	18851	18876	18902	18927	2.6
.6	18953	18978	19004	19029	19054	2.5
.7	19080	19105	19130	19156	19181	2.5
.8	19206	19231	19256	19282	19307	2.5
.9	19332	19357	19382	19407	19432	2.5
21 .0	19457	19482	19507	19532	19557	2.5
.1	19582	19606	19631	19656	19681	2.5
.2	19706	19730	19755	19780	19804	2.5
.3	19829	19854	19878	19903	19927	2.5
.4	19952	19976	20001	20025	20050	2.5
.5	20074	20098	20123	20147	20172	2.5
.6	20196	20220	20244	20269	20293	2.4
.7	20317	20341	20365	20389	20413	2.4
.8	20438	20462	20486	20510	20534	2.4
.9	20558	20581	20605	20629	20653	2.4
22 .0	20677	20701	20725	20748	20772	2.4
.1	20796	20820	20843	20867	20891	2.4
.2	20914	20938	20962	20985	21009	2.4
.3	21032	21056	21079	21103	21126	2.4
.4	21150	21173	21196	21220	21243	2.3
.5	21266	21290	21313	21336	21359	2.3
.6	21383	21406	21429	21452	21475	2.3
.7	21498	21522	21545	21568	21591	2.3
.8	21614	21637	21660	21683	21706	2.3
.9	21728	21751	21774	21797	21820	2.3
23 .0	21843	21866	21888	21911	21934	2.3
.1	21957	21979	22002	22025	22047	2.3
.2	22070	22092	22115	22138	22160	2.3
.3	22183	22205	22228	22250	22272	2.2
.4	22295	22317	22340	22362	22384	2.2
.5	22407	22429	22451	22474	22496	2.2
.6	22518	22540	22562	22585	22607	2.2
.7	22629	22651	22673	22695	22717	2.2
.8	22739	22761	22783	22805	22827	2.2
.9	22849	22871	22893	22915	22937	2.2
24 .0	22959	22981	23003	23024	23046	2.2
.1	23068	23090	23111	23133	23155	2.2
.2	23176	23198	23220	23241	23263	2.2
.3	23285	23306	23328	23349	23371	2.2
.4	23392	23414	23435	23457	23478	2.2
.5	23500	23521	23542	23564	23585	2.1
.6	23606	23628	23649	23670	23692	2.1
.7	23713	23734	23755	23776	23798	2.1
.8	23819	23840	23861	23882	23903	2.1
.9	23924	23945	23966	23987	24008	2.1

Barom- eter. Inches = <i>h</i> .	0.00	0.02	0.04	0.06	0.08	Diff. per .002 in.
25 .0	24029	24050	24071	24092	24113	2.1
.1	24134	24155	24176	24197	24217	2.1
.2	24238	24259	24280	24301	24321	2.1
.3	24342	24363	24384	24404	24425	2.1
.4	24446	24466	24487	24508	24528	2.1
.5	24549	24569	24590	24610	24631	2.1
.6	24651	24672	24692	24713	24733	2.0
.7	24754	24774	24794	24815	24835	2.0
.8	24855	24876	24896	24916	24937	2.0
.9	24957	24977	24997	25018	25038	2.0
26 .0	25058	25078	25098	25118	25138	2.0
.1	25159	25179	25199	25219	25239	2.0
.2	25259	25279	25299	25319	25339	2.0
.3	25359	25379	25399	25419	25438	2.0
.4	25458	25478	25498	25518	25538	2.0
.5	25557	25577	25597	25617	25637	2.0
.6	25656	25676	25696	25715	25735	2.0
.7	25755	25774	25794	25813	25833	2.0
.8	25853	25872	25892	25911	25931	2.0
.9	25950	25970	25989	26009	26028	2.0
27 .0	26048	26067	26086	26106	26125	1.9
.1	26145	26164	26183	26203	26222	1.9
.2	26241	26260	26280	26299	26318	1.9
.3	26337	26357	26376	26395	26414	1.9
.4	26433	26452	26472	26491	26510	1.9
.5	26529	26548	26567	26586	26605	1.9
.6	26624	26643	26662	26681	26700	1.9
.7	26719	26738	26757	26776	26795	1.9
.8	26813	26832	26851	26870	26889	1.9
.9	26908	26926	26945	26964	26983	1.9
28 .0	27001	27020	27039	27058	27076	1.9
.1	27095	27114	27132	27151	27169	1.9
.2	27188	27207	27225	27244	27262	1.9
.3	27281	27299	27318	27336	27355	1.8
.4	27373	27392	27410	27429	27447	1.8
.5	27466	27484	27502	27521	27539	1.8
.6	27557	27576	27594	27612	27631	1.8
.7	27649	27667	27685	27704	27722	1.8
.8	27740	27758	27777	27795	27813	1.8
.9	27831	27849	27867	27885	27904	1.8
29 .0	27922	27940	27958	27976	27994	1.8
.1	28012	28030	28048	28066	28084	1.8
.2	28102	28120	28138	28156	28174	1.8
.3	28192	28209	28227	28245	28263	1.8
.4	28281	28299	28317	28334	28352	1.8
.5	28370	28388	28405	28423	28441	1.8
.6	28459	28476	28494	28512	28529	1.8
.7	28547	28565	28582	28600	28618	1.8
.8	28635	28653	28670	28688	28706	1.8
.9	28723	28741	28758	28776	28793	1.8
30 .0	28811	28828	28846	28863	28881	1.8
.1	28898	28915	28933	28950	28968	1.8
.2	28985	29002	29020	29037	29054	1.7
.3	29072	29089	29106	29124	29141	1.7
.4	29158	29175	29192	29210	29227	1.7
.5	29244	29261	29278	29296	29313	1.7
.6	29330	29347	29364	29381	29398	1.7
.7	29416	29433	29450	29467	29484	1.7
.8	29501	29518	29535	29552	29569	1.7
.9	29586	29603	29620	29637	29654	1.7

TABLE XVI.—COEFFICIENT OF CORRECTION FOR TEMPERATURE

$t+t'$	$t+t'-64^{\circ}$ 900	$t+t'$	$t+t'-64^{\circ}$ 900	$t+t'$	$t+t'-64^{\circ}$ 900	$t+t'$	$t+t'-64^{\circ}$ 900
20°	.0489	65°	+.0011	110°	+.0511	155°	.1011
21	— .0478	66	.0022	111	.0522	156	.1022
22	.0467	67	.0033	112	.0533	157	.1033
23	.0456	68	.0044	113	.0544	158	.1044
24	.0444	69	.0056	114	.0556	159	.1056
25	.0433	70	.0067	115	.0567	160	.1067
26	.0422	71	.0078	116	.0578	161	.1078
27	.0411	72	.0089	117	.0589	162	.1089
28	.0400	73	.0100	118	.0600	163	.1100
29	.0389	74	.0111	119	.0611	164	.1111
30	.0378	75	.0122	120	+.0622	165	.1122
31	— .0367	76	+.0133	121	.0633	166	+.1133
32	.0356	77	.0144	122	.0644	167	.1144
33	.0344	78	.0156	123	.0656	168	.1156
34	.0333	79	.0167	124	.0667	169	.1167
35	.0322	80	.0178	125	.0678	170	.1178
36	.0311	81	.0189	126	.0689	171	.1189
37	.0300	82	.0200	127	.0700	172	.1200
38	.0289	83	.0211	128	.0711	173	.1211
39	.0278	84	.0222	129	.0722	174	.1222
40	.0267	85	.0233	130	+.0733	175	.1233
41	— .0256	86	+.0244	131	.0744	176	+.1244
42	.0244	87	.0256	132	.0756	177	.1256
43	.0233	88	.0267	133	.0767	178	.1267
44	.0222	89	.0278	134	.0778	179	.1278
45	.0211	90	.0289	135	.0789	180	.1289
46	.0200	91	.0300	136	.0800	181	.1300
47	.0189	92	.0311	137	.0811	182	.1311
48	.0178	93	.0322	138	.0822	183	.1322
49	.0167	94	.0333	139	.0833	184	.1333
50	— .0156	95	.0344	140	+.0844	185	.1344
51	.0144	96	+.0356	141	.0856	186	+.1356
52	.0133	97	.0367	142	.0867	187	.1367
53	.0122	98	.0378	143	.0878	188	.1378
54	.0111	99	.0389	144	.0889	189	.1389
55	.0100	100	.0400	145	.0900	190	.1400
56	.0089	101	.0411	146	.0911	191	.1411
57	.0078	102	.0422	147	.0922	192	.1422
58	.0067	103	.0433	148	.0933	193	.1433
59	.0056	104	.0444	149	.0944	194	.1444
60	.0044	105	.0456	150	+.0956	195	.1456
61	— .0033	106	+.0467	151	.0967	196	+.1467
62	.0022	107	.0478	152	.0978	197	.1478
63	.0011	108	.0489	153	.0989	198	.1489
64	.0000	109	.0500	154	.1000	199	.1500

TABLE XVII.—CORRECTION FOR EARTH'S CURVATURE AND REFRACTION

L°	H°	L°	H°	L°	H°	L°	H°	L°	H°	Miles	H°
800	.002	1300	.035	2300	.108	3300	.223	4300	.379	1	.571
400	.003	1400	.040	2400	.118	3400	.237	4400	.397	2	2.285
500	.005	1500	.046	2500	.128	3500	.251	4500	.415	3	5.142
600	.007	1600	.052	2600	.139	3600	.266	4600	.434	4	9.141
700	.010	1700	.059	2700	.149	3700	.281	4700	.453	5	14.282
800	.013	1800	.066	2800	.161	3800	.296	4800	.472	6	20.567
900	.017	1900	.074	2900	.172	3900	.312	4900	.492	7	27.994
1000	.020	2000	.082	3000	.184	4000	.328	5000	.512	8	36.563
1100	.025	2100	.090	3100	.197	4100	.345	5100	.533	9	46.275
1200	.030	2200	.099	3200	.210	4200	.362	5200	.554	10	57.130

DIFFERENCES IN ELEVATION

Minutes.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0	.00	1.74	3.49	5.23	6.96	8.68	10.40	12.10	13.78	15.45
2	.06	1.80	3.55	5.28	7.02	8.74	10.45	12.15	13.84	15.51
4	.12	1.86	3.60	5.34	7.07	8.80	10.51	12.21	13.89	15.56
6	.17	1.92	3.66	5.40	7.13	8.85	10.57	12.26	13.95	15.62
8	.23	1.98	3.72	5.46	7.19	8.91	10.62	12.32	14.01	15.67
10	.29	2.04	3.78	5.52	7.25	8.97	10.68	12.38	14.06	15.73
12	.35	2.09	3.84	5.57	7.30	9.03	10.74	12.43	14.12	15.78
14	.41	2.15	3.90	5.63	7.36	9.08	10.79	12.49	14.17	15.84
16	.47	2.21	3.95	5.69	7.42	9.14	10.85	12.55	14.23	15.89
18	.52	2.27	4.01	5.75	7.48	9.20	10.91	12.60	14.28	15.95
20	.58	2.33	4.07	5.80	7.53	9.25	10.96	12.66	14.34	16.00
22	.64	2.38	4.13	5.86	7.59	9.31	11.02	12.72	14.40	16.06
24	.70	2.44	4.18	5.92	7.65	9.37	11.08	12.77	14.45	16.11
26	.76	2.50	4.24	5.98	7.71	9.43	11.13	12.83	14.51	16.17
28	.81	2.56	4.30	6.04	7.76	9.48	11.19	12.88	14.56	16.22
30	.87	2.62	4.36	6.09	7.82	9.54	11.25	12.94	14.62	16.28
32	.93	2.67	4.42	6.15	7.88	9.60	11.30	13.00	14.67	16.33
34	.99	2.73	4.48	6.21	7.94	9.65	11.36	13.05	14.73	16.39
36	1.05	2.79	4.53	6.27	7.99	9.71	11.42	13.11	14.79	16.44
38	1.11	2.85	4.59	6.33	8.05	9.77	11.47	13.17	14.84	16.50
40	1.16	2.91	4.65	6.38	8.11	9.83	11.53	13.22	14.90	16.55
42	1.22	2.97	4.71	6.44	8.17	9.88	11.59	13.28	14.95	16.61
44	1.28	3.02	4.76	6.50	8.22	9.94	11.64	13.33	15.01	16.66
46	1.34	3.08	4.82	6.56	8.28	10.00	11.70	13.39	15.06	16.72
48	1.40	3.14	4.88	6.61	8.34	10.05	11.76	13.45	15.12	16.77
50	1.45	3.20	4.94	6.67	8.40	10.11	11.81	13.50	15.17	16.83
52	1.51	3.26	4.99	6.73	8.45	10.17	11.87	13.56	15.23	16.88
54	1.57	3.31	5.05	6.78	8.51	10.22	11.93	13.61	15.28	16.94
56	1.63	3.37	5.11	6.84	8.57	10.28	11.98	13.67	15.34	16.99
58	1.69	3.43	5.17	6.90	8.63	10.34	12.04	13.73	15.40	17.05
60	1.74	3.49	5.23	6.96	8.68	10.40	12.10	13.78	15.45	17.10
<i>f+c</i>										
.75	.01	.02	.03	.05	.06	.07	.08	.10	.11	.12
1.00	.01	.03	.04	.06	.08	.09	.11	.13	.15	.16
1.25	.02	.03	.05	.08	.10	.11	.14	.16	.18	.21

CORRECTIONS TO HORIZONTAL DISTANCES

Vertical Angle.	0'	10'	20'	30'	40'	50'	Vertical Angle.
0°	....	....	....	.01	.01	.02	0°
1	.03	.04	.05	.07	.08	.10	1
2	.12	.14	.17	.19	.22	.24	2
3	.27	.31	.34	.37	.41	.45	3
4	.49	.53	.57	.62	.66	.71	4
5	.76	.81	.86	.92	.98	1.03	5
6	1.09	1.15	1.22	1.28	1.35	1.42	6
7	1.49	1.56	1.63	1.70	1.78	1.86	7
8	1.94	2.02	2.10	2.18	2.27	2.36	8
9	2.45	2.54	2.63	2.72	2.82	2.92	9

DIFFERENCES IN ELEVATION

Minutes.	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°
0	17.10	18.73	20.34	21.92	23.47	25.00	26.50	27.96	29.39	30.78
2	17.16	18.78	20.39	21.97	23.52	25.05	26.55	28.01	29.44	30.83
4	17.21	18.84	20.44	22.02	23.58	25.10	26.59	28.06	29.48	30.87
6	17.26	18.89	20.50	22.08	23.63	25.15	26.64	28.10	29.53	30.92
8	17.32	18.95	20.55	22.13	23.68	25.20	26.69	28.15	29.58	30.97
10	17.37	19.00	20.60	22.18	23.73	25.25	26.74	28.20	29.62	31.01
12	17.43	19.05	20.66	22.23	23.78	25.30	26.79	28.25	29.67	31.06
14	17.48	19.11	20.71	22.28	23.83	25.35	26.84	28.30	29.72	31.10
16	17.54	19.16	20.76	22.34	23.88	25.40	26.89	28.34	29.76	31.15
18	17.59	19.21	20.81	22.39	23.93	25.45	26.94	28.39	29.81	31.19
20	17.65	19.27	20.87	22.44	23.99	25.50	26.99	28.44	29.86	31.24
22	17.70	19.32	20.92	22.49	24.04	25.55	27.04	28.49	29.90	31.28
24	17.76	19.38	20.97	22.54	24.09	25.60	27.09	28.54	29.95	31.32
26	17.81	19.43	21.03	22.60	24.14	25.65	27.13	28.58	30.00	31.38
28	17.86	19.48	21.08	22.65	24.19	25.70	27.18	28.63	30.04	31.42
30	17.92	19.54	21.13	22.70	24.24	25.75	27.23	28.68	30.09	31.47
32	17.97	19.59	21.18	22.75	24.29	25.80	27.28	28.73	30.14	31.51
34	18.03	19.64	21.24	22.80	24.34	25.85	27.33	28.77	30.19	31.56
36	18.08	19.70	21.29	22.85	24.39	25.90	27.38	28.82	30.23	31.60
38	18.14	19.75	21.34	22.91	24.44	25.95	27.43	28.87	30.28	31.65
40	18.19	19.80	21.39	22.96	24.49	26.00	27.48	28.92	30.32	31.69
42	18.24	19.86	21.45	23.01	24.55	26.05	27.52	28.96	30.37	31.74
44	18.30	19.91	21.50	23.06	24.60	26.10	27.57	29.01	30.41	31.78
46	18.35	19.96	21.55	23.11	24.65	26.15	27.62	29.06	30.46	31.83
48	18.41	20.02	21.60	23.16	24.70	26.20	27.67	29.11	30.51	31.87
50	18.46	20.07	21.66	23.22	24.75	26.25	27.72	29.15	30.55	31.92
52	18.51	20.12	21.71	23.27	24.80	26.30	27.77	29.20	30.60	31.96
54	18.57	20.18	21.76	23.32	24.85	26.35	27.81	29.25	30.65	32.01
56	18.62	20.23	21.81	23.37	24.90	26.40	27.86	29.30	30.69	32.05
58	18.68	20.28	21.87	23.42	24.95	26.45	27.91	29.34	30.74	32.09
60	18.73	20.34	21.92	23.47	25.00	26.50	27.96	29.39	30.78	32.14
$f+c$										
.75	.14	.15	.16	.17	.19	.20	.21	.23	.24	.25
1.00	.18	.20	.22	.23	.25	.27	.28	.30	.32	.33
1.25	.23	.25	.27	.29	.31	.34	.36	.38	.40	.42

CORRECTIONS TO HORIZONTAL DISTANCES

Vertical Angle.	0'	10'	20'	30'	40'	50'	Vertical Angle.
10°	3.02	3.12	3.22	3.32	3.43	3.53	10°
11	3.64	3.75	3.86	3.97	4.09	4.21	11
12	4.32	4.44	4.56	4.68	4.81	4.93	12
13	5.06	5.19	5.32	5.45	5.58	5.72	13
14	5.85	5.99	6.13	6.27	6.41	6.55	14
15	6.70	6.84	6.99	7.14	7.29	7.44	15
16	7.60	7.75	7.91	8.07	8.23	8.39	16
17	8.55	8.71	8.88	9.04	9.21	9.38	17
18	9.55	9.72	9.89	10.07	10.24	10.42	18
19	10.60	10.78	10.96	11.14	11.33	11.51	19

DIFFERENCES IN ELEVATION

Minutes.	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°
0	32.14	33.46	34.73	35.97	37.16	38.30	39.40	40.45	41.45	42.40
2	32.18	33.50	34.77	36.01	37.20	38.34	39.44	40.49	41.48	42.43
4	32.23	33.54	34.82	36.05	37.23	38.38	39.47	40.52	41.52	42.46
6	32.27	33.59	34.86	36.09	37.27	38.41	39.51	40.55	41.55	42.49
8	32.32	33.63	34.90	36.13	37.31	38.45	39.54	40.59	41.58	42.53
10	32.36	33.67	34.94	36.17	37.35	38.49	39.58	40.62	41.61	42.56
12	32.41	33.72	34.98	36.21	37.39	38.53	39.61	40.66	41.65	42.59
14	32.45	33.76	35.02	36.25	37.43	38.56	39.65	40.69	41.68	42.62
16	32.49	33.80	35.07	36.29	37.47	38.60	39.69	40.72	41.71	42.65
18	32.54	33.84	35.11	36.33	37.51	38.64	39.72	40.76	41.74	42.68
20	32.58	33.89	35.15	36.37	37.54	38.67	39.76	40.79	41.77	42.71
22	32.63	33.93	35.19	36.41	37.58	38.71	39.79	40.82	41.81	42.74
24	32.67	33.97	35.23	36.45	37.62	38.75	39.83	40.86	41.84	42.77
26	32.72	34.01	35.27	36.49	37.66	38.78	39.86	40.89	41.87	42.80
28	32.76	34.06	35.31	36.53	37.70	38.82	39.90	40.92	41.90	42.83
30	32.80	34.10	35.36	36.57	37.74	38.86	39.93	40.96	41.93	42.86
32	32.85	34.14	35.40	36.61	37.77	38.89	39.97	40.99	41.97	42.89
34	32.89	34.18	35.44	36.65	37.81	38.93	40.00	41.02	42.00	42.92
36	32.93	34.23	35.48	36.69	37.85	38.97	40.04	41.06	42.03	42.95
38	32.98	34.27	35.52	36.73	37.89	39.00	40.07	41.09	42.06	42.98
40	33.02	34.31	35.56	36.77	37.93	39.04	40.11	41.12	42.09	43.01
42	33.07	34.35	35.60	36.80	37.96	39.08	40.14	41.16	42.12	43.04
44	33.11	34.40	35.64	36.84	38.00	39.11	40.18	41.19	42.15	43.07
46	33.15	34.44	35.68	36.88	38.04	39.15	40.21	41.22	42.19	43.10
48	33.20	34.48	35.72	36.92	38.08	39.18	40.24	41.26	42.22	43.13
50	33.24	34.52	35.76	36.96	38.11	39.22	40.28	41.29	42.25	43.16
52	33.28	34.57	35.80	37.00	38.15	39.26	40.31	41.32	42.28	43.18
54	33.33	34.61	35.85	37.04	38.19	39.29	40.35	41.35	42.31	43.21
56	33.37	34.65	35.89	37.08	38.23	39.33	40.38	41.39	42.34	43.24
58	33.41	34.69	35.93	37.12	38.26	39.36	40.42	41.42	42.37	43.27
60	33.46	34.73	35.97	37.16	38.30	39.40	40.45	41.45	42.40	43.30
<i>f + c</i>										
.75	.26	.27	.29	.30	.31	.32	.33	.35	.36	.37
1.00	.35	.37	.38	.40	.41	.43	.45	.46	.47	.48
1.25	.44	.46	.48	.50	.52	.54	.56	.58	.60	.62

CORRECTIONS TO HORIZONTAL DISTANCES

Vertical Angle.	0'	10'	20'	30'	40'	50'	Vertical Angle.
20°	11.70	11.89	12.07	12.26	12.46	12.65	20°
21	12.84	13.04	13.23	13.43	13.63	13.83	21
22	14.03	14.24	14.44	14.64	14.85	15.06	22
23	15.27	15.48	15.69	15.90	16.11	16.33	23
24	16.54	16.76	16.98	17.20	17.42	17.64	24
25	17.86	18.08	18.31	18.53	18.76	18.99	25
26	19.22	19.45	19.68	19.91	20.14	20.38	26
27	20.61	20.85	21.08	21.32	21.56	21.80	27
28	22.04	22.28	22.52	22.77	23.01	23.26	28
29	23.50	23.75	24.00	24.25	24.50	24.75	29

Latitude.		Hour Angle.	DECLINATIONS.									
			+20°	+15°	+10°	+5°	0°	-5°	-10°	-15°	-20°	
2° 30'	0 h		-18"	-12"	-07"	-02"	02"	07"	12"	18"	23"	
	2		-18	-12	-07	-02	02	07	12	18	23	
	3		-17	-11	-06	-01	03	08	13	19	25	
	4		-15	-10	-05	00	05	10	15	21	27	
	5		-10	-05	00	+05	10	15	20	26	32	
5°	0 h		-15"	-10"	-05"	00"	05"	10"	15"	20"	27"	
	2		-15	-10	-05	00	05	10	15	20	27	
	3		-13	-08	-03	+02	07	12	17	23	29	
	4		-10	-05	00	+05	10	15	20	27	32	
	5		-05	00	+05	+10	15	20	27	32	40	
7° 30'	0 h		-13"	-08"	-02"	32"	08"	13"	18"	24"	29"	
	2		-12	-07	-01	03	09	14	19	25	31	
	3		-10	-05	00	05	10	15	20	26	32	
	4		-05	00	+05	10	15	20	26	32	39	
	5		+07	+12	+17	23	29	36	43	51	1' 01	
10°	0 h		-10"	-05"	00"	05"	10"	15"	20"	26"	32"	
	2		-07	-03	02	07	12	17	22	28	34	
	3		-05	00	03	08	13	19	25	31	38	
	4		00	+05	10	15	20	26	32	39	46	
	5		+15	+20	26	32	39	46	55	1' 06	1' 19	
12° 30'	0 h		-08"	-02"	02"	08"	13"	18"	24"	30"	36"	
	2		-06	00	05	10	15	20	26	32	39	
	3		+02	+07	12	17	23	29	36	43	51	
	4		+04	+09	14	20	25	31	40	48	55	
	5		+21	+27	33	40	48	57	1' 08	1' 23	1' 41	
15°	0 h		-05"	00"	05"	10"	15"	21"	27"	33"	40"	
	2		-03	02	07	12	18	23	29	36	43	
	3		+01	05	11	16	22	28	34	41	49	
	4		+08	12	19	24	30	37	44	53	1' 04	
	5		+29	34	41	49	59	1' 10	1' 24	1' 43	2 08	
17° 30'	0 h		-02"	02"	08"	13"	18"	24"	30"	36"	44"	
	2		00	05	10	15	21	27	33	40	48	
	3		+02	10	15	21	27	33	40	48	57	
	4		+13	18	23	29	35	43	51	1' 01	1' 13	
	5		+34	41	49	58	1' 10	1' 23	1' 41	2 06	2 42	
20°	0 h		00"	05"	10"	15"	21"	27"	33"	40"	48"	
	2		03	07	13	18	24	30	36	44	52	
	3		06	13	18	24	30	36	44	52	1' 02	
	4		17	22	28	35	42	50	1' 00	1' 11	1 26	
	5		39	47	57	1' 07	1' 20	1' 37	2 00	2 32	3 25	
22° 30'	0 h		02"	08"	13"	18"	24"	30"	36"	44"	52"	
	2		06	11	15	21	27	33	40	48	57	
	3		11	15	21	27	33	40	48	57	1' 08	
	4		20	26	32	39	46	56	1' 07	1' 19	1 37	
	5		45	53	1' 03	1' 16	1' 31	1' 52	2 21	3 07	4 28	
25°	0 h		05"	10"	15"	21"	27"	33"	40"	48"	57"	
	2		08	14	19	25	31	38	46	54	1' 05	
	3		12	18	24	30	37	44	53	04	1 18	
	4		23	29	35	45	53	1' 03	1' 16	1 31	1 52	
	5		49	59	1' 10	1' 24	1' 52	2 07	2 44	3 46	5 43	
			+20°	+15°	+10°	+5°	0°	-5°	-10°	-15°	-20°	

Latitude	Hour Angle.	DECLINATIONS.								
		+20°	+15°	+10°	+5°	0°	-5°	-10°	-15°	-20°
27° 30'	0 h	08''	13''	18''	24''	30''	36''	44''	52''	1' 02''
	1	11	16	22	28	34	41	49	1' 00	1 10
	2	17	22	28	35	42	50	1' 00	1 11	1 26
	3	23	35	42	50	1' 00	1' 11	1 26	1 43	2 09
	4	54	1' 05	1' 18	1' 34	1 54	2 24	3 11	4 38	8 15
30°	0 h	10''	15''	21''	27''	33''	40''	48''	57''	1' 08''
	1	14	19	25	31	38	46	54	1' 05	1 18
	2	20	26	32	39	47	55	1' 06	1 19	1 36
	3	32	39	46	52	1' 06	1' 15	1 35	1 57	2 29
	4	1' 00	1' 10	1' 24	1' 52	2 07	2 44	3 46	5 43	13 06
32° 30'	0 h	13''	18''	24''	30''	36''	44''	52''	1' 02''	1' 14''
	1	17	22	28	35	42	50	1' 00	1 11	1 26
	2	23	29	35	43	51	1' 01	1 13	1 28	1 47
	3	35	43	51	1' 01	1' 13	1 27	1 46	2 13	2 54
	4	1' 03	1' 15	1' 31	1 53	2 20	3 05	4 25	7 36	
35°	0 h	15''	21''	27''	33''	40''	48''	57''	1' 08''	1' 21''
	1	20	25	32	38	46	55	1' 05	1 18	1 35
	2	26	33	39	47	56	1' 07	1 21	1 38	2 00
	3	39	47	56	1' 07	1' 20	1 36	1 59	2 32	3 25
	4	1' 07	1' 20	1' 38	2 00	2 34	3 29	5 14	10 16	
37° 30'	0 h	18''	24''	30''	36''	44''	52''	1' 02''	1' 14''	1' 29''
	1	22	28	35	42	50	1' 00	1 12	1 26	1 45
	2	29	36	43	52	1' 02	1 14	1 29	1 49	2 16
	3	43	51	1' 01	1' 13	1 27	1 49	2 14	2 54	4 05
	4	1' 11	1' 26	1 54	2 10	2 49	3 55	6 15	14 58	
40°	0 h	21''	27''	33''	40''	48''	57''	1' 08''	1' 21''	1' 39''
	1	25	32	39	46	52	1' 06	1 19	1 35	1 57
	2	33	40	48	57	1' 08	1 21	1 38	2 02	2 36
	3	47	55	1' 06	1' 19	1 36	1 58	2 30	3 21	4 59
	4	1' 15	1' 31	1 51	2 20	3 05	4 25	7 34	25 18	
42° 30'	0 h	24''	30''	36''	44''	52''	1' 02''	1' 14''	1' 29''	1' 49''
	1	28	35	39	50	1' 00	1 12	1 26	1 45	2 11
	2	36	43	52	1' 02	1 13	1 29	1 49	2 17	2 59
	3	50	1' 00	1' 11	1 26	1 44	2 10	2 49	3 55	6 16
	4	1' 19	1 36	1 58	2 30	3 22	5 00	9 24		
45°	0 h	27''	33''	40''	48''	57''	1' 08''	1' 21''	1' 39''	2' 02''
	1	32	39	46	52	1' 06	1 19	1 35	1 57	2 29
	2	40	47	56	1' 07	1 21	1 38	2 00	2 34	3 29
	3	54	1' 04	1' 16	1 33	1 54	2 24	3 11	4 38	8 15
	4	1' 23	1 41	2 05	2 41	3 40	5 40	12 02		
47° 30'	0 h	30''	36''	44''	52''	1' 02''	1' 14''	1' 29''	1' 49''	2' 18''
	1	35	42	50	1' 00	1 12	1 26	1 45	2 01	2 51
	2	43	51	1' 01	1 13	1 28	1 47	2 15	2 56	4 08
	3	56	1' 09	1 23	1 40	2 05	2 40	3 39	5 37	11 18
	4	1' 27	1 46	2 12	2 52	4 01	6 30	16 19		
		+20°	+15°	+10°	+5°	0°	-5°	-10°	-15°	-20°

Latitude.	Hour Angle.	DECLINATIONS.								
		+20°	+15°	+10°	+5°	0°	-5°	-10°	-15°	-20°
50°	0 h	33"	40"	48"	57"	1' 08"	1' 21"	1' 39"	2' 02"	2' 36"
	1	38	46	55	1' 06	1 18	1 35	1 57	2 28	3 19
	2	47	56	1' 06	1 19	1 36	2 29	2 31	3 23	5 02
	3	1' 02	1' 14	1 29	1 48	2 16	2 58	4 18	6 59	19 47
	4	1 30	1 51	2 19	3 04	4 22	7 28	24 10		
52° 30'	0 h	36"	44"	52"	1' 02"	1' 14"	1' 29"	1' 49"	2' 18"	3' 05"
	1	43	50	59	1 11	1 26	1 42	2 23	2 49	3 55
	2	50	1' 00	1' 11	1 26	1 45	2 11	2 51	2 58	6 22
	3	1' 05	1 18	1 35	2 10	2 28	3 19	4 53	8 42	
	4	1 34	1 56	2 27	3 16	4 47	8 52			
55°	0 h	40"	48"	57"	1' 08"	1' 21"	1' 39"	2' 02"	2' 36"	3' 33"
	1	46	55	1' 05	1 18	1 34	1 55	2 30	3 15	4 47
	2	55	1' 06	1 19	1 35	1 58	2 30	3 21	4 58	9 19
	3	1' 10	1 23	1 42	2 06	2 43	3 44	5 49	12 41	
	4	1 37	2 01	2 34	3 28	5 15	10 18			
57° 30'	0 h	44"	52"	1' 02"	1' 14"	1' 29"	1' 49"	2' 18"	3' 05"	4' 37"
	1	50	59	1 11	1 25	1 43	2 09	2 47	3 51	6 04
	2	58	1' 10	1 24	1 42	2 07	2 43	3 45	5 50	12 47
	3	1' 11	1 25	1 43	2 10	2 50	3 55	6 14	14 49	
	4	1 41	2 06	2 42	3 42	5 46	12 26			
60°	0 h	48"	57"	1' 08"	1' 21"	1' 39"	2' 02"	2' 36"	3' 33"	5' 23"
	1	54	1' 04	1 17	1 33	1 54	2 24	3 12	4 38	8 15
	2	1' 03	1 15	1 30	1 51	2 20	3 04	4 24	7 31	24 44
	3	1 18	1 34	1 56	2 28	3 18	4 50	8 53		
	4	1 45	2 11	2 50	3 57	6 21	15 32			
62° 30'	0 h	52"	1' 02"	1' 14"	1' 29"	1' 50	2' 18"	3' 00"	4' 17"	7' 13"
	1	58	1 09	1 23	1 41	2 06	2 43	3 44	5 50	12 44
	2	1' 07	1 23	1 38	2 01	2 35	3 30	5 16	10 24	
	3	1 23	1 40	2 05	2 40	3 40	5 37	11 50		
	4	1 48	2 17	2 59	4 14	7 03				
65°	0 h	57"	1' 08"	1' 21"	1' 39"	2' 02"	2' 36"	3' 33"	5' 23"	10' 51"
	1	1' 03	1 16	1 31	1 52	2 21	3 07	4 28	7 44	
	2	1 12	1 27	1 46	2 12	2 52	4 02	6 33		
	3	1 27	1 47	2 13	2 54	4 05	6 40			
	4	1 52	2 22	3 08	4 30	7 52				
67° 30'	0 h	1' 02"	1' 14"	1' 29"	1' 50"	2' 18"	3' 00"	4' 17"	7' 13"	
	1	1 08	1 22	1 40	2 03	2 39	3 37	5 32	11 28	
	2	1 17	1 34	1 55	2 26	3 14	4 44	8 34		
	3	1 32	1 53	2 23	3 14	4 35	8 05			
	4	1 56	2 28	3 17	4 40	8 51				
70°	0 h	1' 08"	1' 21"	1' 39"	2' 02"	2' 36"	3' 33"	5' 23"	10' 51"	
	1	1 14	1 29	1 50	2 18	3 00	4 17	7 13		
	2	1 23	1 43	2 05	2 41	3 41	5 59	12 15		
	3	1 37	2 00	2 34	3 28	5 20	10 12			
	4	2 02	2 33	3 27	5 11	10 05				
		+20°	+15°	+10°	+5°	0°	-5°	-10°	-15°	-20°

TABLE XXA.—LENGTHS OF CIRCULAR ARCS; RADIUS = 1 43
by Sol A. Bauer

Length of Arc; Radius = 1										Decimals	
Arc (deg.)			Arc (min.)		Arc (sec.)		P.P.		Min.		Sec.
0	60	1.04719755	0				484.81				0
1	.01745329	61	1.06465084	1	.00029089	.00000485	1	48	.016	.00027	1
2	.03490659	62	1.08210414	2	.00058178	.00000970	2	97	.033	.00055	2
3	.05235988	63	1.09955743	3	.00087266	.00001454	3	145	.050	.00083	3
4	.06981317	64	1.11701072	4	.00116355	.00001939	4	194	.066	.00111	4
5	.08726646	65	1.13446401	5	.00145444	.00002424	5	242	.083	.00138	5
6	.10471976	66	1.15191731	6	.00174533	.00002909	6	291	.100	.00166	6
7	.12217305	67	1.16937060	7	.00203622	.00003394	7	339	.116	.00194	7
8	.13962634	68	1.18682389	8	.00232711	.00003879	8	388	.133	.00222	8
9	.15707963	69	1.20427718	9	.00261799	.00004363	9	436	.150	.00250	9
10	.17453329	70	1.22173048	10	.00290888	.00004848			.166	.00277	10
11	.19198622	71	1.23918377	11	.00319977	.00005333			.183	.00305	11
12	.20943951	72	1.25663706	12	.00349066	.00005818			.200	.00333	12
13	.22689280	73	1.27409035	13	.00378155	.00006303			.216	.00361	13
14	.24434610	74	1.29154365	14	.00407243	.00006787			.233	.00388	14
15	.26179939	75	1.30899694	15	.00436332	.00007272			.250	.00416	15
16	.27925268	76	1.32645023	16	.00465421	.00007757			.266	.00444	16
17	.29670597	77	1.34390352	17	.00494510	.00008242			.283	.00472	17
18	.31415927	78	1.36135682	18	.00523599	.00008727			.300	.00500	18
19	.33161256	79	1.37881011	19	.00552688	.00009211			.316	.00527	19
20	.34906585	80	1.39626340	20	.00581776	.00009696			.333	.00555	20
21	.36651914	81	1.41371669	21	.00610865	.00010181			.350	.00583	21
22	.38397244	82	1.43116999	22	.00639954	.00010666			.366	.00611	22
23	.40142573	83	1.44862328	23	.00669043	.00011151			.383	.00638	23
24	.41887902	84	1.46607657	24	.00698132	.00011636			.400	.00666	24
25	.43633231	85	1.48352986	25	.00727221	.00012120			.416	.00694	25
26	.45378561	86	1.50098316	26	.00756309	.00012605			.433	.00722	26
27	.47123890	87	1.51843645	27	.00785398	.00013090			.450	.00750	27
28	.48869219	88	1.53588974	28	.00814487	.00013575			.466	.00777	28
29	.50614548	89	1.55334303	29	.00843576	.00014060			.483	.00805	29
30	.52359878	90	1.57079633	30	.00872665	.00014544			.500	.00833	30
31	.54105207	91	1.58824962	31	.00901753	.00015029			.516	.00861	31
32	.55850536	92	1.60570291	32	.00930842	.00015514			.533	.00888	32
33	.57595865	93	1.62315620	33	.00959931	.00015999			.550	.00916	33
34	.59341195	94	1.64060950	34	.00989020	.00016484			.566	.00944	34
35	.61086524	95	1.65806279	35	.01018109	.00016968			.583	.00972	35
36	.62831853	96	1.67551608	36	.01047198	.00017453			.600	.01000	36
37	.64577182	97	1.69296937	37	.01076286	.00017938			.616	.01027	37
38	.66322512	98	1.71042267	38	.01105375	.00018423			.633	.01055	38
39	.68067841	99	1.72787596	39	.01134464	.00018908			.650	.01083	39
40	.69813170	100	1.74532925	40	.01163553	.00019393			.666	.01111	40
41	.71558499	101	1.76278254	41	.01192642	.00019877			.683	.01138	41
42	.73303829	102	1.78023584	42	.01221730	.00020362			.700	.01166	42
43	.75049158	103	1.79768913	43	.01250819	.00020847			.716	.01194	43
44	.76794487	104	1.81514242	44	.01279908	.00021332			.733	.01222	44
45	.78539816	105	1.83259571	45	.01308997	.00021817			.750	.01250	45
46	.80285146	106	1.85004901	46	.01338086	.00022301			.766	.01277	46
47	.82030475	107	1.86750230	47	.01367175	.00022786			.783	.01305	47
48	.83775804	108	1.88495559	48	.01396263	.00023271			.800	.01333	48
49	.85521133	109	1.90240888	49	.01425352	.00023756			.816	.01361	49
50	.87266463	110	1.91986218	50	.01454441	.00024241			.833	.01388	50
51	.89011792	111	1.93731547	51	.01483530	.00024725			.850	.01416	51
52	.90757121	112	1.95476876	52	.01512619	.00025210			.866	.01444	52
53	.92502450	113	1.97222205	53	.01541707	.00025695			.883	.01472	53
54	.94247780	114	1.98967535	54	.01570796	.00026180			.900	.01500	54
55	.95993109	115	2.00712864	55	.01599885	.00026665			.916	.01527	55
56	.97738438	116	2.02458193	56	.01628974	.00027150			.933	.01555	56
57	.99483767	117	2.04203522	57	.01658063	.00027634			.950	.01583	57
58	1.01229097	118	2.05948852	58	.01687152	.00028119			.966	.01611	58
59	1.02974426	119	2.07694181	59	.01716240	.00028604			.983	.01638	59

$A - C = 2R (0.0087, 2664, 63\Delta - \sin \Delta/2)$ when $\Delta = 90^\circ$ $A - C = 0.1565828$.
Area segment = $R^2 (0.0087, 2664, 626\Delta - \frac{1}{2} \sin \Delta)$ when $\Delta = 90^\circ$, area = R^2
(0.2853, 9817).

Copyright, 1947, by Sol A. Bauer.

by Sol A. Bauer

Min.	1°	2°	3°	4°	5°	6°	7°	Min.
					Diff. 03	Diff. 04	Diff. 05	
0	.0000002	.0000018	.0000060	.0000142	.0000277	.0000478	.0000760	0
1					.0000280	.0000482	.0000765	1
2					.0000282	.0000486	.0000770	2
3					.0000285	.0000490	.0000776	3
4					.0000288	.0000494	.0000781	4
5	.0000003	.0000020	.0000065	.0000151	.0000291	.0000498	.0000787	5
6					.0000293	.0000502	.0000792	6
7					.0000296	.0000506	.0000798	7
8					.0000299	.0000510	.0000804	8
9					.0000302	.0000514	.0000809	9
10	.0000003	.0000022	.0000070	.0000161	.0000305	.0000519	.0000815	10
11					.0000308	.0000524	.0000821	11
12					.0000311	.0000528	.0000827	12
13					.0000314	.0000532	.0000832	13
14					.0000317	.0000536	.0000838	14
15	.0000004	.0000025	.0000076	.0000170	.0000320	.0000541	.0000844	15
16					.0000323	.0000545	.0000850	16
17					.0000326	.0000549	.0000855	17
18					.0000329	.0000553	.0000861	18
19					.0000332	.0000558	.0000867	19
20	.0000005	.0000028	.0000082	.0000180	.0000336	.0000563	.0000874	20
21					.0000339	.0000567	.0000880	21
22					.0000342	.0000571	.0000886	22
23					.0000345	.0000576	.0000892	23
24					.0000349	.0000580	.0000898	24
25	.0000006	.0000031	.0000088	.0000191	.0000352	.0000585	.0000904	25
26					.0000355	.0000589	.0000910	26
27					.0000358	.0000594	.0000916	27
28					.0000361	.0000599	.0000922	28
29					.0000365	.0000603	.0000928	29
30	.0000007	.0000035	.0000095	.0000202	.0000368	.0000608	.0000934	30
31					.0000372	.0000613	.0000941	31
32					.0000375	.0000618	.0000947	32
33					.0000378	.0000623	.0000953	33
34					.0000382	.0000627	.0000959	34
35	.0000009	.0000038	.0000102	.0000213	.0000385	.0000632	.0000966	35
36					.0000389	.0000637	.0000972	36
37					.0000392	.0000642	.0000978	37
38					.0000395	.0000646	.0000985	38
39					.0000399	.0000651	.0000991	39
40	.0000010	.0000042	.0000109	.0000225	.0000403	.0000656	.0000998	40
41					.0000407	.0000661	.0001005	41
42					.0000410	.0000666	.0001011	42
43					.0000414	.0000671	.0001018	43
44					.0000417	.0000676	.0001024	44
45	.0000012	.0000046	.0000117	.0000237	.0000421	.0000681	.0001031	45
46					.0000424	.0000686	.0001037	46
47					.0000428	.0000691	.0001044	47
48					.0000432	.0000696	.0001050	48
49					.0000436	.0000701	.0001057	49
50	.0000014	.0000050	.0000125	.0000250	.0000440	.0000707	.0001065	50
51					.0000444	.0000712	.0001071	51
52					.0000447	.0000717	.0001078	52
53					.0000451	.0000722	.0001085	53
54					.0000455	.0000727	.0001092	54
55	.0000016	.0000055	.0000133	.0000263	.0000459	.0000733	.0001099	55
56					.0000462	.0000738	.0001106	56
57					.0000466	.0000743	.0001113	57
58					.0000470	.0000748	.0001120	58
59					.0000474	.0000754	.0001127	59
60	.0000018	.0000060	.0000142	.0000277	.0000478	.0000760	.0001134	60

Min.	8°	9°	10°	11°	12°	13°	14°	Min.
	Diff. 07	Diff. 09	Diff. 11	Diff. 13	Diff. 16	Diff. 19	Diff. 22	
0	.0001134	.0001614	.0002214	.0002947	.0003826	.0004864	.0006074	0
1	.0001141	.0001623	.0002225	.0002960	.0003842	.0004883	.0006096	1
2	.0001148	.0001632	.0002236	.0002974	.0003858	.0004901	.0006118	2
3	.0001155	.0001641	.0002248	.0002987	.0003874	.0004920	.0006139	3
4	.0001162	.0001650	.0002259	.0003001	.0003890	.0004939	.0006162	4
5	.0001169	.0001659	.0002270	.0003014	.0003906	.0004958	.0006183	5
6	.0001177	.0001668	.0002281	.0003028	.0003922	.0004977	.0006205	6
7	.0001184	.0001677	.0002292	.0003041	.0003938	.0004996	.0006227	7
8	.0001191	.0001687	.0002303	.0003055	.0003954	.0005015	.0006249	8
9	.0001198	.0001696	.0002315	.0003069	.0003971	.0005034	.0006271	9
10	.0001206	.0001706	.0002327	.0003083	.0003987	.0005053	.0006294	10
11	.0001214	.0001715	.0002338	.0003097	.0004004	.0005072	.0006316	11
12	.0001221	.0001724	.0002350	.0003111	.0004020	.0005092	.0006338	12
13	.0001228	.0001734	.0002361	.0003125	.0004037	.0005111	.0006360	13
14	.0001236	.0001743	.0002373	.0003138	.0004053	.0005130	.0006383	14
15	.0001243	.0001752	.0002384	.0003152	.0004070	.0005150	.0006405	15
16	.0001251	.0001762	.0002396	.0003166	.0004086	.0005169	.0006427	16
17	.0001258	.0001771	.0002407	.0003180	.0004103	.0005189	.0006450	17
18	.0001266	.0001781	.0002419	.0003194	.0004120	.0005208	.0006472	18
19	.0001273	.0001791	.0002431	.0003209	.0004137	.0005228	.0006495	19
20	.0001282	.0001801	.0002443	.0003223	.0004154	.0005247	.0006518	20
21	.0001289	.0001810	.0002455	.0003237	.0004170	.0005267	.0006541	21
22	.0001297	.0001820	.0002467	.0003252	.0004187	.0005287	.0006564	22
23	.0001305	.0001830	.0002479	.0003266	.0004204	.0005307	.0006587	23
24	.0001313	.0001839	.0002491	.0003280	.0004221	.0005327	.0006609	24
25	.0001320	.0001849	.0002503	.0003295	.0004238	.0005347	.0006632	25
26	.0001328	.0001859	.0002515	.0003309	.0004255	.0005367	.0006655	26
27	.0001336	.0001869	.0002527	.0003324	.0004272	.0005387	.0006678	27
28	.0001344	.0001879	.0002539	.0003338	.0004289	.0005407	.0006701	28
29	.0001352	.0001889	.0002551	.0003353	.0004307	.0005427	.0006725	29
30	.0001360	.0001899	.0002563	.0003367	.0004324	.0005447	.0006748	30
31	.0001368	.0001909	.0002576	.0003382	.0004341	.0005467	.0006771	31
32	.0001376	.0001919	.0002588	.0003397	.0004359	.0005487	.0006795	32
33	.0001384	.0001929	.0002600	.0003412	.0004376	.0005507	.0006818	33
34	.0001392	.0001939	.0002612	.0003426	.0004393	.0005528	.0006841	34
35	.0001400	.0001949	.0002625	.0003441	.0004411	.0005548	.0006865	35
36	.0001409	.0001959	.0002637	.0003456	.0004428	.0005569	.0006888	36
37	.0001417	.0001969	.0002649	.0003471	.0004446	.0005589	.0006912	37
38	.0001425	.0001980	.0002662	.0003486	.0004463	.0005610	.0006936	38
39	.0001433	.0001990	.0002674	.0003501	.0004481	.0005631	.0006959	39
40	.0001442	.0002000	.0002687	.0003516	.0004499	.0005651	.0006983	40
41	.0001450	.0002011	.0002700	.0003531	.0004517	.0005671	.0007007	41
42	.0001458	.0002021	.0002713	.0003546	.0004535	.0005692	.0007031	42
43	.0001467	.0002031	.0002725	.0003561	.0004553	.0005713	.0007055	43
44	.0001475	.0002042	.0002738	.0003576	.0004570	.0005734	.0007079	44
45	.0001484	.0002052	.0002750	.0003592	.0004588	.0005755	.0007103	45
46	.0001492	.0002063	.0002763	.0003607	.0004606	.0005776	.0007127	46
47	.0001501	.0002074	.0002776	.0003622	.0004624	.0005797	.0007151	47
48	.0001509	.0002084	.0002789	.0003638	.0004642	.0005818	.0007175	48
49	.0001518	.0002095	.0002802	.0003653	.0004661	.0005839	.0007199	49
50	.0001526	.0002106	.0002815	.0003669	.0004679	.0005860	.0007224	50
51	.0001535	.0002116	.0002828	.0003684	.0004697	.0005881	.0007248	51
52	.0001544	.0002127	.0002841	.0003700	.0004716	.0005902	.0007273	52
53	.0001553	.0002138	.0002854	.0003715	.0004734	.0005924	.0007297	53
54	.0001561	.0002149	.0002868	.0003730	.0004752	.0005945	.0007322	54
55	.0001570	.0002160	.0002881	.0003747	.0004771	.0005967	.0007346	55
56	.0001579	.0002171	.0002894	.0003763	.0004789	.0005988	.0007371	56
57	.0001588	.0002182	.0002907	.0003778	.0004808	.0006010	.0007396	57
58	.0001597	.0002193	.0002920	.0003794	.0004826	.0006031	.0007420	58
59	.0001606	.0002204	.0002934	.0003810	.0004845	.0006053	.0007445	59
60	.0001614	.0002214	.0002947	.0003826	.0004864	.0006074	.0007470	60

Min.	15°	16°	17°	18°	19°	20°	21°	Min.
	Diff. 25	Diff. 28	Diff. 32	Diff. 36	Diff. 40	Diff. 44	Diff. 49	
0	.0007470	.0009065	.0010872	.0012903	.0015173	.0017695	.0020481	0
1	.0007495	.0009093	.0010904	.0012939	.0015213	.0017739	.0020530	1
2	.0007520	.0009121	.0010936	.0012975	.0015253	.0017784	.0020579	2
3	.0007545	.0009150	.0010968	.0013011	.0015293	.0017828	.0020628	3
4	.0007570	.0009178	.0011000	.0013047	.0015333	.0017873	.0020677	4
5	.0007595	.0009206	.0011032	.0013083	.0015374	.0017917	.0020726	5
6	.0007620	.0009235	.0011065	.0013120	.0015414	.0017962	.0020775	6
7	.0007646	.0009264	.0011097	.0013156	.0015454	.0018007	.0020824	7
8	.0007671	.0009292	.0011130	.0013192	.0015495	.0018051	.0020873	8
9	.0007696	.0009321	.0011162	.0013229	.0015535	.0018096	.0020923	9
10	.0007722	.0009351	.0011194	.0013265	.0015576	.0018141	.0020972	10
11	.0007747	.0009380	.0011227	.0013301	.0015616	.0018186	.0021021	11
12	.0007773	.0009409	.0011260	.0013338	.0015657	.0018231	.0021071	12
13	.0007798	.0009438	.0011292	.0013375	.0015698	.0018276	.0021121	13
14	.0007824	.0009467	.0011325	.0013412	.0015739	.0018321	.0021171	14
15	.0007850	.0009496	.0011358	.0013448	.0015780	.0018367	.0021221	15
16	.0007875	.0009525	.0011391	.0013485	.0015821	.0018412	.0021271	16
17	.0007901	.0009554	.0011424	.0013522	.0015862	.0018458	.0021321	17
18	.0007927	.0009583	.0011457	.0013559	.0015903	.0018503	.0021371	18
19	.0007953	.0009613	.0011490	.0013596	.0015944	.0018549	.0021421	19
20	.0007979	.0009643	.0011523	.0013633	.0015985	.0018594	.0021471	20
21	.0008005	.0009672	.0011557	.0013670	.0016027	.0018639	.0021521	21
22	.0008031	.0009702	.0011590	.0013707	.0016068	.0018685	.0021571	22
23	.0008057	.0009731	.0011623	.0013744	.0016110	.0018731	.0021622	23
24	.0008084	.0009761	.0011657	.0013782	.0016151	.0018777	.0021672	24
25	.0008110	.0009791	.0011690	.0013820	.0016193	.0018823	.0021723	25
26	.0008136	.0009821	.0011724	.0013857	.0016235	.0018869	.0021774	26
27	.0008163	.0009851	.0011758	.0013895	.0016277	.0018915	.0021825	27
28	.0008189	.0009880	.0011792	.0013933	.0016319	.0018962	.0021876	28
29	.0008216	.0009910	.0011825	.0013970	.0016361	.0019008	.0021927	29
30	.0008242	.0009941	.0011858	.0014008	.0016402	.0019054	.0021977	30
31	.0008268	.0009971	.0011892	.0014046	.0016444	.0019101	.0022028	31
32	.0008295	.0010001	.0011926	.0014084	.0016486	.0019147	.0022079	32
33	.0008322	.0010031	.0011960	.0014122	.0016529	.0019194	.0022131	33
34	.0008348	.0010062	.0011994	.0014160	.0016571	.0019241	.0022182	34
35	.0008375	.0010092	.0012029	.0014198	.0016613	.0019287	.0022233	35
36	.0008402	.0010122	.0012063	.0014236	.0016656	.0019334	.0022285	36
37	.0008429	.0010153	.0012097	.0014275	.0016698	.0019381	.0022337	37
38	.0008456	.0010183	.0012132	.0014313	.0016741	.0019428	.0022388	38
39	.0008483	.0010214	.0012166	.0014352	.0016784	.0019475	.0022440	39
40	.0008510	.0010245	.0012200	.0014390	.0016826	.0019522	.0022492	40
41	.0008538	.0010276	.0012235	.0014428	.0016868	.0019569	.0022544	41
42	.0008565	.0010306	.0012269	.0014467	.0016911	.0019617	.0022596	42
43	.0008592	.0010337	.0012304	.0014506	.0016954	.0019664	.0022648	43
44	.0008619	.0010368	.0012339	.0014544	.0016997	.0019712	.0022700	44
45	.0008647	.0010399	.0012374	.0014583	.0017040	.0019759	.0022752	45
46	.0008674	.0010430	.0012409	.0014622	.0017084	.0019807	.0022804	46
47	.0008702	.0010461	.0012444	.0014661	.0017127	.0019855	.0022857	47
48	.0008729	.0010493	.0012479	.0014700	.0017170	.0019903	.0022909	48
49	.0008757	.0010524	.0012514	.0014740	.0017214	.0019950	.0022962	49
50	.0008785	.0010555	.0012548	.0014778	.0017257	.0019998	.0023014	50
51	.0008812	.0010587	.0012584	.0014817	.0017300	.0020046	.0023067	51
52	.0008840	.0010618	.0012619	.0014856	.0017344	.0020094	.0023120	52
53	.0008868	.0010650	.0012654	.0014895	.0017387	.0020142	.0023172	53
54	.0008896	.0010681	.0012690	.0014934	.0017431	.0020190	.0023225	54
55	.0008924	.0010713	.0012725	.0014974	.0017475	.0020239	.0023278	55
56	.0008952	.0010744	.0012761	.0015014	.0017519	.0020287	.0023331	56
57	.0008980	.0010776	.0012796	.0015054	.0017563	.0020336	.0023385	57
58	.0009008	.0010808	.0012832	.0015093	.0017607	.0020384	.0023438	58
59	.0009036	.0010840	.0012868	.0015133	.0017651	.0020432	.0023491	59
60	.0009065	.0010872	.0012903	.0015173	.0017695	.0020481	.0023544	60

TABLE XXB.—ARC MINUS CHORD WHEN RADIUS = 1

Min.	22°	23°	24°	25°	26°	27°	28°	Min.
	Diff. 54	Diff. 59	Diff. 64	Diff. 69	Diff. 75	Diff. 80	Diff. 86	
0	.0023544	.0026899	.0030556	.0034531	.0038835	.0043482	.0048484	0
1	.0023598	.0026957	.0030620	.0034600	.0038910	.0043562	.0048570	1
2	.0023652	.0027016	.0030684	.0034669	.0038984	.0043642	.0048657	2
3	.0023705	.0027074	.0030748	.0034738	.0039059	.0043723	.0048744	3
4	.0023759	.0027133	.0030811	.0034808	.0039134	.0043803	.0048831	4
5	.0023813	.0027192	.0030875	.0034877	.0039209	.0043884	.0048918	5
6	.0023867	.0027250	.0030939	.0034946	.0039284	.0043965	.0049005	6
7	.0023921	.0027309	.0031004	.0035016	.0039359	.0044046	.0049092	7
8	.0023975	.0027368	.0031068	.0035085	.0039434	.0044128	.0049179	8
9	.0024029	.0027427	.0031132	.0035156	.0039509	.0044209	.0049266	9
10	.0024083	.0027487	.0031196	.0035225	.0039585	.0044290	.0049353	10
11	.0024137	.0027546	.0031261	.0035295	.0039661	.0044372	.0049441	11
12	.0024192	.0027605	.0031326	.0035365	.0039736	.0044453	.0049528	12
13	.0024246	.0027665	.0031390	.0035435	.0039812	.0044535	.0049616	13
14	.0024301	.0027724	.0031455	.0035505	.0039888	.0044617	.0049703	14
15	.0024356	.0027784	.0031520	.0035576	.0039964	.0044698	.0049791	15
16	.0024410	.0027844	.0031585	.0035646	.0040040	.0044780	.0049879	16
17	.0024465	.0027903	.0031650	.0035716	.0040116	.0044862	.0049967	17
18	.0024520	.0027963	.0031715	.0035787	.0040192	.0044944	.0050055	18
19	.0024575	.0028023	.0031780	.0035857	.0040269	.0045027	.0050144	19
20	.0024630	.0028084	.0031845	.0035928	.0040345	.0045109	.0050233	20
21	.0024685	.0028144	.0031911	.0035999	.0040422	.0045191	.0050321	21
22	.0024740	.0028204	.0031976	.0036070	.0040498	.0045274	.0050410	22
23	.0024795	.0028264	.0032042	.0036141	.0040575	.0045357	.0050499	23
24	.0024850	.0028325	.0032107	.0036212	.0040652	.0045439	.0050587	24
25	.0024906	.0028385	.0032173	.0036283	.0040729	.0045522	.0050676	25
26	.0024961	.0028446	.0032239	.0036355	.0040806	.0045605	.0050765	26
27	.0025017	.0028506	.0032305	.0036426	.0040883	.0045688	.0050854	27
28	.0025073	.0028567	.0032371	.0036498	.0040960	.0045771	.0050944	28
29	.0025128	.0028628	.0032437	.0036569	.0041037	.0045854	.0051033	29
30	.0025184	.0028689	.0032503	.0036641	.0041115	.0045938	.0051123	30
31	.0025240	.0028750	.0032569	.0036712	.0041192	.0046021	.0051212	31
32	.0025296	.0028811	.0032636	.0036784	.0041270	.0046105	.0051302	32
33	.0025352	.0028872	.0032702	.0036856	.0041348	.0046188	.0051391	33
34	.0025409	.0028933	.0032769	.0036928	.0041425	.0046272	.0051481	34
35	.0025465	.0028995	.0032835	.0037001	.0041503	.0046356	.0051571	35
36	.0025521	.0029056	.0032902	.0037073	.0041581	.0046440	.0051661	36
37	.0025578	.0029118	.0032969	.0037145	.0041659	.0046524	.0051751	37
38	.0025634	.0029179	.0033036	.0037218	.0041738	.0046608	.0051841	38
39	.0025691	.0029241	.0033103	.0037290	.0041816	.0046692	.0051932	39
40	.0025747	.0029303	.0033170	.0037363	.0041894	.0046776	.0052023	40
41	.0025804	.0029365	.0033237	.0037436	.0041973	.0046861	.0052113	41
42	.0025861	.0029427	.0033304	.0037508	.0042051	.0046945	.0052204	42
43	.0025918	.0029489	.0033372	.0037581	.0042130	.0047030	.0052295	43
44	.0025975	.0029551	.0033439	.0037654	.0042209	.0047114	.0052385	44
45	.0026032	.0029613	.0033507	.0037727	.0042287	.0047199	.0052476	45
46	.0026089	.0029675	.0033574	.0037801	.0042366	.0047284	.0052567	46
47	.0026146	.0029738	.0033642	.0037874	.0042445	.0047369	.0052659	47
48	.0026204	.0029800	.0033710	.0037947	.0042524	.0047454	.0052750	48
49	.0026261	.0029863	.0033778	.0038021	.0042603	.0047539	.0052841	49
50	.0026319	.0029925	.0033846	.0038094	.0042683	.0047625	.0052933	50
51	.0026376	.0029988	.0033914	.0038168	.0042762	.0047710	.0053025	51
52	.0026434	.0030051	.0033982	.0038242	.0042842	.0047796	.0053117	52
53	.0026492	.0030114	.0034051	.0038315	.0042922	.0047882	.0053209	53
54	.0026550	.0030177	.0034119	.0038389	.0043001	.0047967	.0053300	54
55	.0026608	.0030240	.0034187	.0038463	.0043081	.0048053	.0053392	55
56	.0026666	.0030303	.0034256	.0038538	.0043161	.0048139	.0053485	56
57	.0026724	.0030366	.0034325	.0038612	.0043241	.0048225	.0053577	57
58	.0026782	.0030430	.0034394	.0038686	.0043321	.0048311	.0053669	58
59	.0026840	.0030493	.0034462	.0038760	.0043401	.0048397	.0053762	59
60	.0026899	.0030556	.0034531	.0038835	.0043482	.0048484	.0053855	60

Min.	29°	30°	31°	32°	33°	34°	35°	Mtn.
	Diff. 92	Diff. 99	Diff. 106	Diff. 113	Diff. 120	Diff. 127	Diff. 135	
0	.0053855	.0059607	.0065753	.0072307	.0079280	.0086685	.0094536	0
1	.0053947	.0059706	.0065859	.0072419	.0079400	.0086813	.0094671	1
2	.0054040	.0059805	.0065965	.0072532	.0079520	.0086940	.0094806	2
3	.0054133	.0059905	.0066071	.0072645	.0079640	.0087067	.0094941	3
4	.0054226	.0060004	.0066177	.0072758	.0079760	.0087195	.0095076	4
5	.0054319	.0060104	.0066284	.0072872	.0079880	.0087323	.0095211	5
6	.0054413	.0060204	.0066390	.0072985	.0080001	.0087450	.0095347	6
7	.0054506	.0060304	.0066496	.0073098	.0080121	.0087578	.0095482	7
8	.0054599	.0060404	.0066603	.0073212	.0080242	.0087706	.0095618	8
9	.0054693	.0060504	.0066710	.0073325	.0080363	.0087834	.0095754	9
10	.0054787	.0060604	.0066817	.0073439	.0080484	.0087963	.0095890	10
11	.0054880	.0060704	.0066924	.0073553	.0080605	.0088091	.0096026	11
12	.0054974	.0060804	.0067031	.0073667	.0080726	.0088220	.0096162	12
13	.0055068	.0060905	.0067138	.0073781	.0080847	.0088348	.0096298	13
14	.0055162	.0061005	.0067245	.0073896	.0080969	.0088477	.0096434	14
15	.0055257	.0061106	.0067353	.0074010	.0081090	.0088606	.0096571	15
16	.0055351	.0061207	.0067460	.0074125	.0081212	.0088735	.0096707	16
17	.0055445	.0061308	.0067568	.0074239	.0081334	.0088864	.0096844	17
18	.0055540	.0061409	.0067676	.0074354	.0081455	.0088994	.0096981	18
19	.0055634	.0061510	.0067784	.0074469	.0081577	.0089123	.0097118	19
20	.0055729	.0061611	.0067892	.0074584	.0081700	.0089252	.0097255	20
21	.0055824	.0061713	.0068000	.0074699	.0081822	.0089382	.0097392	21
22	.0055919	.0061814	.0068108	.0074814	.0081944	.0089512	.0097529	22
23	.0056014	.0061916	.0068217	.0074929	.0082067	.0089642	.0097667	23
24	.0056109	.0062017	.0068325	.0075045	.0082189	.0089772	.0097804	24
25	.0056204	.0062119	.0068434	.0075160	.0082312	.0089902	.0097942	25
26	.0056300	.0062221	.0068542	.0075276	.0082435	.0090032	.0098080	26
27	.0056395	.0062323	.0068651	.0075392	.0082558	.0090162	.0098218	27
28	.0056491	.0062425	.0068760	.0075508	.0082681	.0090293	.0098356	28
29	.0056587	.0062528	.0068869	.0075624	.0082804	.0090423	.0098494	29
30	.0056682	.0062630	.0068978	.0075740	.0082928	.0090554	.0098633	30
31	.0056778	.0062733	.0069088	.0075856	.0083051	.0090685	.0098771	31
32	.0056874	.0062835	.0069197	.0075973	.0083175	.0090816	.0098910	32
33	.0056970	.0062938	.0069306	.0076089	.0083299	.0090948	.0099049	33
34	.0057067	.0063041	.0069416	.0076206	.0083422	.0091079	.0099188	34
35	.0057163	.0063143	.0069526	.0076323	.0083546	.0091210	.0099327	35
36	.0057259	.0063246	.0069636	.0076439	.0083670	.0091342	.0099466	36
37	.0057356	.0063350	.0069745	.0076556	.0083795	.0091474	.0099605	37
38	.0057453	.0063453	.0069855	.0076674	.0083919	.0091605	.0099745	38
39	.0057550	.0063556	.0069966	.0076791	.0084044	.0091737	.0099884	39
40	.0057646	.0063660	.0070076	.0076908	.0084168	.0091869	.0100024	40
41	.0057743	.0063763	.0070186	.0077025	.0084293	.0092002	.0100164	41
42	.0057840	.0063867	.0070297	.0077143	.0084418	.0092134	.0100304	42
43	.0057938	.0063971	.0070408	.0077261	.0084543	.0092266	.0100444	43
44	.0058035	.0064075	.0070518	.0077379	.0084668	.0092399	.0100584	44
45	.0058132	.0064179	.0070629	.0077496	.0084793	.0092531	.0100725	45
46	.0058230	.0064283	.0070740	.0077614	.0084918	.0092664	.0100865	46
47	.0058328	.0064387	.0070851	.0077733	.0085043	.0092797	.0101006	47
48	.0058425	.0064492	.0070963	.0077851	.0085169	.0092930	.0101146	48
49	.0058523	.0064596	.0071074	.0077969	.0085295	.0093063	.0101287	49
50	.0058621	.0064701	.0071186	.0078088	.0085421	.0093197	.0101428	50
51	.0058719	.0064806	.0071297	.0078206	.0085546	.0093330	.0101569	51
52	.0058818	.0064910	.0071409	.0078325	.0085672	.0093463	.0101711	52
53	.0058916	.0065015	.0071521	.0078444	.0085799	.0093597	.0101852	53
54	.0059014	.0065120	.0071633	.0078563	.0085925	.0093731	.0101994	54
55	.0059113	.0065226	.0071745	.0078682	.0086051	.0093865	.0102135	55
56	.0059211	.0065331	.0071857	.0078801	.0086178	.0093999	.0102277	56
57	.0059310	.0065436	.0071969	.0078921	.0086305	.0094133	.0102419	57
58	.0059409	.0065542	.0072081	.0079040	.0086432	.0094267	.0102561	58
59	.0059508	.0065647	.0072194	.0079160	.0086558	.0094402	.0102703	59
60	.0059607	.0065753	.0072307	.0079280	.0086685	.0094536	.0102846	60

Min.	36°	37°	38°	39°	40°	41°	42°	Min.
	Diff. 142	Diff. 150	Diff. 158	Diff. 167	Diff. 175	Diff. 184	Diff. 193	
0	.0102846	.0111625	.0120888	.0130647	.0140914	.0151702	.0163024	0
1	.0102988	.0111776	.0121047	.0130814	.0141090	.0151887	.0163217	1
2	.0103131	.0111926	.0121205	.0130981	.0141266	.0152071	.0163411	2
3	.0103273	.0112077	.0121364	.0131148	.0141441	.0152256	.0163604	3
4	.0103416	.0112228	.0121523	.0131316	.0141617	.0152440	.0163798	4
5	.0103559	.0112378	.0121682	.0131483	.0141793	.0152625	.0163992	5
6	.0103702	.0112530	.0121842	.0131651	.0141970	.0152810	.0164186	6
7	.0103845	.0112681	.0122001	.0131818	.0142146	.0152995	.0164380	7
8	.0103989	.0112832	.0122160	.0131986	.0142322	.0153181	.0164574	8
9	.0104132	.0112984	.0122320	.0132154	.0142499	.0153366	.0164769	9
10	.0104276	.0113135	.0122480	.0132323	.0142676	.0153552	.0164963	10
11	.0104420	.0113287	.0122640	.0132491	.0142853	.0153738	.0165158	11
12	.0104564	.0113439	.0122800	.0132660	.0143030	.0153924	.0165353	12
13	.0104708	.0113591	.0122960	.0132828	.0143207	.0154110	.0165548	13
14	.0104852	.0113743	.0123120	.0132997	.0143384	.0154296	.0165744	14
15	.0104996	.0113895	.0123281	.0133166	.0143562	.0154482	.0165939	15
16	.0105140	.0114048	.0123442	.0133335	.0143740	.0154669	.0166135	16
17	.0105285	.0114200	.0123602	.0133504	.0143917	.0154855	.0166330	17
18	.0105429	.0114353	.0123763	.0133673	.0144095	.0155042	.0166526	18
19	.0105574	.0114506	.0123924	.0133843	.0144273	.0155229	.0166722	19
20	.0105719	.0114659	.0124085	.0134012	.0144452	.0155416	.0166918	20
21	.0105864	.0114812	.0124247	.0134182	.0144630	.0155604	.0167115	21
22	.0106009	.0114965	.0124408	.0134352	.0144809	.0155791	.0167311	22
23	.0106155	.0115118	.0124570	.0134522	.0144987	.0155979	.0167508	23
24	.0106300	.0115272	.0124732	.0134692	.0145166	.0156166	.0167705	24
25	.0106446	.0115425	.0124893	.0134863	.0145345	.0156354	.0167902	25
26	.0106591	.0115579	.0125055	.0135033	.0145524	.0156542	.0168099	26
27	.0106737	.0115733	.0125218	.0135204	.0145704	.0156730	.0168296	27
28	.0106883	.0115887	.0125380	.0135374	.0145883	.0156919	.0168493	28
29	.0107029	.0116041	.0125542	.0135545	.0146063	.0157107	.0168691	29
30	.0107176	.0116195	.0125705	.0135716	.0146243	.0157296	.0168889	30
31	.0107322	.0116350	.0125867	.0135887	.0146422	.0157485	.0169086	31
32	.0107469	.0116504	.0126030	.0136059	.0146602	.0157674	.0169284	32
33	.0107615	.0116659	.0126193	.0136230	.0146783	.0157863	.0169483	33
34	.0107762	.0116814	.0126356	.0136402	.0146963	.0158052	.0169681	34
35	.0107909	.0116969	.0126520	.0136573	.0147143	.0158241	.0169879	35
36	.0108056	.0117124	.0126683	.0136745	.0147324	.0158431	.0170078	36
37	.0108203	.0117279	.0126847	.0136917	.0147505	.0158620	.0170277	37
38	.0108351	.0117435	.0127010	.0137090	.0147685	.0158810	.0170476	38
39	.0108498	.0117590	.0127174	.0137262	.0147866	.0159000	.0170675	39
40	.0108646	.0117746	.0127338	.0137435	.0148048	.0159190	.0170874	40
41	.0108793	.0117902	.0127502	.0137607	.0148229	.0159380	.0171073	41
42	.0108941	.0118058	.0127666	.0137780	.0148410	.0159571	.0171273	42
43	.0109089	.0118214	.0127831	.0137953	.0148592	.0159761	.0171473	43
44	.0109237	.0118370	.0127995	.0138126	.0148774	.0159952	.0171672	44
45	.0109386	.0118526	.0128160	.0138299	.0148956	.0160143	.0171872	45
46	.0109534	.0118683	.0128325	.0138473	.0149138	.0160334	.0172073	46
47	.0109682	.0118839	.0128490	.0138646	.0149320	.0160525	.0172273	47
48	.0109831	.0118996	.0128655	.0138820	.0149502	.0160716	.0172473	48
49	.0109980	.0119153	.0128820	.0138993	.0149685	.0160908	.0172674	49
50	.0110129	.0119310	.0128985	.0139167	.0149868	.0161099	.0172875	50
51	.0110278	.0119467	.0129151	.0139341	.0150050	.0161291	.0173076	51
52	.0110427	.0119625	.0129317	.0139516	.0150233	.0161483	.0173277	52
53	.0110576	.0119782	.0129482	.0139690	.0150417	.0161675	.0173478	53
54	.0110726	.0119940	.0129648	.0139864	.0150600	.0161867	.0173680	54
55	.0110875	.0120098	.0129814	.0140039	.0150783	.0162060	.0173881	55
56	.0111025	.0120255	.0129981	.0140214	.0150967	.0162252	.0174083	56
57	.0111175	.0120413	.0130147	.0140389	.0151151	.0162445	.0174285	57
58	.0111325	.0120572	.0130313	.0140564	.0151334	.0162638	.0174487	58
59	.0111475	.0120730	.0130480	.0140739	.0151518	.0162831	.0174689	59
60	.0111625	.0120888	.0130647	.0140914	.0151702	.0163024	.0174891	60

Min.	43°	44°	45°	46°	47°	48°	49°	Min.
	Diff. 202	Diff. 212	Diff. 221	Diff. 231	Diff. 241	Diff. 251	Diff. 262	
0	.0174891	.0187317	.0200313	.0213892	.0228066	.0242848	.0258248	0
1	.0175094	.0187529	.0200535	.0214123	.0228307	.0243099	.0258510	1
2	.0175296	.0187741	.0200756	.0214355	.0228549	.0243351	.0258773	2
3	.0175499	.0187953	.0200978	.0214586	.0228791	.0243603	.0259035	3
4	.0175702	.0188165	.0201200	.0214818	.0229033	.0243855	.0259298	4
5	.0175905	.0188378	.0201422	.0215050	.0229275	.0244107	.0259560	5
6	.0176108	.0188591	.0201644	.0215282	.0229517	.0244360	.0259823	6
7	.0176312	.0188804	.0201867	.0215515	.0229759	.0244612	.0260086	7
8	.0176515	.0189017	.0202090	.0215747	.0230002	.0244865	.0260349	8
9	.0176719	.0189230	.0202312	.0215980	.0230244	.0245118	.0260613	9
10	.0176923	.0189443	.0202535	.0216213	.0230487	.0245371	.0260876	10
11	.0177127	.0189657	.0202758	.0216446	.0230730	.0245624	.0261140	11
12	.0177331	.0189870	.0202982	.0216679	.0230974	.0245878	.0261404	12
13	.0177536	.0190084	.0203205	.0216912	.0231217	.0246131	.0261668	13
14	.0177740	.0190298	.0203429	.0217146	.0231460	.0246385	.0261933	14
15	.0177945	.0190512	.0203653	.0217379	.0231704	.0246639	.0262197	15
16	.0178150	.0190726	.0203877	.0217613	.0231948	.0246893	.0262462	16
17	.0178355	.0190941	.0204101	.0217847	.0232192	.0247148	.0262726	17
18	.0178560	.0191155	.0204325	.0218081	.0232436	.0247402	.0262991	18
19	.0178765	.0191370	.0204549	.0218316	.0232681	.0247657	.0263257	19
20	.0178970	.0191585	.0204774	.0218550	.0232925	.0247912	.0263522	20
21	.0179176	.0191800	.0204999	.0218785	.0233170	.0248167	.0263788	21
22	.0179382	.0192015	.0205224	.0219019	.0233415	.0248422	.0264053	22
23	.0179588	.0192231	.0205449	.0219254	.0233660	.0248677	.0264319	23
24	.0179794	.0192446	.0205674	.0219490	.0233905	.0248933	.0264585	24
25	.0180000	.0192662	.0205899	.0219725	.0234151	.0249189	.0264851	25
26	.0180206	.0192878	.0206125	.0219960	.0234396	.0249445	.0265118	26
27	.0180413	.0193094	.0206351	.0220196	.0234642	.0249701	.0265384	27
28	.0180620	.0193310	.0206577	.0220432	.0234888	.0249957	.0265651	28
29	.0180826	.0193526	.0206803	.0220668	.0235134	.0250213	.0265918	29
30	.0181033	.0193743	.0207029	.0220904	.0235380	.0250470	.0266185	30
31	.0181241	.0193960	.0207255	.0221140	.0235627	.0250727	.0266452	31
32	.0181448	.0194176	.0207482	.0221377	.0235873	.0250984	.0266720	32
33	.0181655	.0194393	.0207709	.0221613	.0236120	.0251241	.0266987	33
34	.0181863	.0194611	.0207935	.0221850	.0236367	.0251498	.0267255	34
35	.0182071	.0194828	.0208163	.0222087	.0236614	.0251755	.0267523	35
36	.0182279	.0195045	.0208390	.0222324	.0236861	.0252013	.0267791	36
37	.0182487	.0195263	.0208617	.0222562	.0237109	.0252271	.0268060	37
38	.0182695	.0195481	.0208845	.0222799	.0237356	.0252529	.0268328	38
39	.0182903	.0195699	.0209072	.0223037	.0237604	.0252787	.0268597	39
40	.0183112	.0195917	.0209300	.0223275	.0237852	.0253045	.0268866	40
41	.0183321	.0196135	.0209528	.0223513	.0238100	.0253303	.0269135	41
42	.0183530	.0196354	.0209756	.0223751	.0238349	.0253563	.0269404	42
43	.0183739	.0196572	.0209985	.0223989	.0238597	.0253821	.0269674	43
44	.0183948	.0196791	.0210213	.0224227	.0238846	.0254080	.0269943	44
45	.0184157	.0197010	.0210442	.0224466	.0239095	.0254340	.0270213	45
46	.0184367	.0197229	.0210671	.0224705	.0239344	.0254599	.0270483	46
47	.0184577	.0197448	.0210900	.0224944	.0239593	.0254858	.0270753	47
48	.0184786	.0197668	.0211129	.0225183	.0239842	.0255118	.0271023	48
49	.0184996	.0197887	.0211358	.0225422	.0240092	.0255378	.0271294	49
50	.0185207	.0198107	.0211588	.0225662	.0240341	.0255638	.0271565	50
51	.0185417	.0198327	.0211818	.0225902	.0240591	.0255898	.0271835	51
52	.0185627	.0198547	.0212047	.0226141	.0240841	.0256159	.0272106	52
53	.0185838	.0198767	.0212277	.0226381	.0241091	.0256419	.0272378	53
54	.0186049	.0198988	.0212508	.0226622	.0241342	.0256680	.0272649	54
55	.0186260	.0199208	.0212738	.0226862	.0241592	.0256941	.0272921	55
56	.0186471	.0199429	.0212968	.0227102	.0241843	.0257202	.0273192	56
57	.0186682	.0199650	.0213199	.0227343	.0242094	.0257464	.0273464	57
58	.0186893	.0199871	.0213430	.0227584	.0242345	.0257725	.0273736	58
59	.0187105	.0200092	.0213661	.0227825	.0242596	.0257987	.0274009	59
60	.0187317	.0200313	.0213892	.0228066	.0242848	.0258248	.0274281	60

TABLE XXB.—ARC MINUS CHORD WHEN RADIUS = 1 51

Min.	50°	51°	52°	53°	54°	55°	56°	Min.
	Diff. 272	Diff. 283	Diff. 294	Diff. 306	Diff. 317	Diff. 329	Diff. 340	
0	.0274281	.0290957	.0308289	.0326289	.0344968	.0364339	.0384413	0
1	.0274554	.0291241	.0308584	.0326595	.0345285	.0364668	.0384753	1
2	.0274826	.0291524	.0308878	.0326900	.0345602	.0364997	.0385094	2
3	.0275099	.0291808	.0309173	.0327207	.0345920	.0365326	.0385435	3
4	.0275373	.0292092	.0309468	.0327513	.0346238	.0365655	.0385776	4
5	.0275646	.0292376	.0309763	.0327819	.0346556	.0365984	.0386117	5
6	.0275919	.0292661	.0310059	.0328126	.0346874	.0366314	.0386459	6
7	.0276193	.0292945	.0310355	.0328433	.0347192	.0366644	.0386801	7
8	.0276467	.0293230	.0310650	.0328740	.0347510	.0366974	.0387143	8
9	.0276741	.0293515	.0310946	.0329047	.0347829	.0367305	.0387485	9
10	.0277015	.0293800	.0311242	.0329355	.0348148	.0367635	.0387828	10
11	.0277290	.0294085	.0311539	.0329662	.0348467	.0367966	.0388170	11
12	.0277564	.0294371	.0311835	.0329970	.0348786	.0368297	.0388513	12
13	.0277839	.0294656	.0312132	.0330278	.0349106	.0368628	.0388856	13
14	.0278114	.0294942	.0312429	.0330586	.0349426	.0368959	.0389199	14
15	.0278389	.0295228	.0312726	.0330895	.0349745	.0369291	.0389542	15
16	.0278665	.0295514	.0313023	.0331203	.0350065	.0369622	.0389886	16
17	.0278940	.0295801	.0313321	.0331512	.0350386	.0369954	.0390230	17
18	.0279216	.0296087	.0313618	.0331821	.0350706	.0370286	.0390574	18
19	.0279492	.0296374	.0313916	.0332130	.0351027	.0370619	.0390918	19
20	.0279768	.0296661	.0314214	.0332439	.0351347	.0370951	.0391262	20
21	.0280044	.0296948	.0314512	.0332749	.0351668	.0371284	.0391607	21
22	.0280320	.0297235	.0314811	.0333058	.0351990	.0371617	.0391952	22
23	.0280597	.0297523	.0315109	.0333368	.0352311	.0371950	.0392297	23
24	.0280874	.0297811	.0315408	.0333678	.0352633	.0372283	.0392642	24
25	.0281151	.0298098	.0315707	.0333989	.0352954	.0372617	.0392987	25
26	.0281428	.0298386	.0316006	.0334299	.0353276	.0372950	.0393333	26
27	.0281705	.0298675	.0316306	.0334610	.0353599	.0373284	.0393679	27
28	.0281982	.0298963	.0316605	.0334921	.0353921	.0373618	.0394025	28
29	.0282260	.0299252	.0316905	.0335232	.0354243	.0373952	.0394371	29
30	.0282538	.0299540	.0317205	.0335543	.0354566	.0374287	.0394717	30
31	.0282816	.0299829	.0317505	.0335854	.0354889	.0374622	.0395064	31
32	.0283094	.0300118	.0317805	.0336166	.0355212	.0374957	.0395410	32
33	.0283373	.0300408	.0318106	.0336478	.0355535	.0375292	.0395757	33
34	.0283651	.0300697	.0318406	.0336790	.0355859	.0375627	.0396104	34
35	.0283930	.0300987	.0318707	.0337102	.0356183	.0375962	.0396452	35
36	.0284209	.0301277	.0319008	.0337414	.0356507	.0376298	.0396800	36
37	.0284488	.0301567	.0319309	.0337727	.0356831	.0376634	.0397147	37
38	.0284767	.0301857	.0319611	.0338039	.0357155	.0376970	.0397495	38
39	.0285047	.0302148	.0319912	.0338352	.0357479	.0377306	.0397843	39
40	.0285326	.0302438	.0320214	.0338665	.0357804	.0377642	.0398192	40
41	.0285606	.0302729	.0320516	.0338979	.0358129	.0377979	.0398540	41
42	.0285886	.0303020	.0320818	.0339292	.0358454	.0378316	.0398889	42
43	.0286166	.0303311	.0321120	.0339606	.0358779	.0378653	.0399238	43
44	.0286447	.0303603	.0321423	.0339920	.0359105	.0378990	.0399587	44
45	.0286727	.0303894	.0321726	.0340234	.0359431	.0379327	.0399937	45
46	.0287008	.0304186	.0322029	.0340548	.0359757	.0379665	.0400286	46
47	.0287289	.0304478	.0322332	.0340863	.0360083	.0380003	.0400636	47
48	.0287570	.0304770	.0322635	.0341177	.0360409	.0380341	.0400986	48
49	.0287851	.0305062	.0322938	.0341492	.0360735	.0380679	.0401336	49
50	.0288133	.0305355	.0323242	.0341807	.0361062	.0381018	.0401687	50
51	.0288414	.0305647	.0323546	.0342122	.0361389	.0381356	.0402037	51
52	.0288696	.0305940	.0323850	.0342438	.0361716	.0381695	.0402388	52
53	.0288978	.0306233	.0324154	.0342753	.0362043	.0382034	.0402739	53
54	.0289260	.0306526	.0324458	.0343069	.0362370	.0382373	.0403090	54
55	.0289543	.0306820	.0324763	.0343385	.0362698	.0382713	.0403442	55
56	.0289825	.0307113	.0325068	.0343701	.0363026	.0383052	.0403793	56
57	.0290108	.0307407	.0325373	.0344018	.0363354	.0383392	.0404145	57
58	.0290391	.0307701	.0325678	.0344334	.0363682	.0383732	.0404497	58
59	.0290674	.0307995	.0325983	.0344651	.0364010	.0384072	.0404849	59
60	.0290957	.0308289	.0326289	.0344968	.0364339	.0384413	.0405202	60

Min.	57°	58°	59°	60°	61°	62°	63°	Min.
	Diff. 352	Diff. 365	Diff. 378	Diff. 390	Diff. 402	Diff. 415	Diff. 429	
0	.0405202	.0426717	.0448971	.0471975	.0495742	.0520280	.0545603	0
1	.0405554	.0427082	.0449349	.0472365	.0496144	.0520696	.0546032	1
2	.0405907	.0427447	.0449726	.0472755	.0496547	.0521111	.0546461	2
3	.0406260	.0427812	.0450104	.0473145	.0496950	.0521527	.0546890	3
4	.0406613	.0428178	.0450482	.0473536	.0497353	.0521944	.0547319	4
5	.0406967	.0428543	.0450860	.0473927	.0497757	.0522360	.0547749	5
6	.0407320	.0428909	.0451238	.0474318	.0498160	.0522777	.0548179	6
7	.0407674	.0429275	.0451616	.0474709	.0498564	.0523194	.0548609	7
8	.0408028	.0429642	.0451995	.0475100	.0498968	.0523611	.0549039	8
9	.0408382	.0430008	.0452374	.0475491	.0499372	.0524028	.0549470	9
10	.0408737	.0430375	.0452753	.0475883	.0499777	.0524446	.0549901	10
11	.0409091	.0430742	.0453132	.0476275	.0500182	.0524863	.0550332	11
12	.0409446	.0431109	.0453512	.0476667	.0500586	.0525281	.0550763	12
13	.0409801	.0431476	.0453892	.0477060	.0500992	.0525700	.0551194	13
14	.0410156	.0431844	.0454272	.0477452	.0501397	.0526118	.0551626	14
15	.0410512	.0432211	.0454652	.0477845	.0501803	.0526537	.0552058	15
16	.0410867	.0432579	.0455032	.0478238	.0502209	.0526956	.0552490	16
17	.0411223	.0432947	.0455412	.0478631	.0502615	.0527375	.0552922	17
18	.0411579	.0433316	.0455793	.0479025	.0503021	.0527794	.0553355	18
19	.0411936	.0433684	.0456174	.0479418	.0503427	.0528213	.0553787	19
20	.0412292	.0434053	.0456555	.0479812	.0503834	.0528633	.0554220	20
21	.0412649	.0434422	.0456937	.0480206	.0504241	.0529053	.0554654	21
22	.0413006	.0434791	.0457318	.0480600	.0504648	.0529473	.0555087	22
23	.0413363	.0435160	.0457700	.0480995	.0505056	.0529894	.0555521	23
24	.0413720	.0435530	.0458082	.0481390	.0505463	.0530314	.0555955	24
25	.0414077	.0435899	.0458465	.0481785	.0505871	.0530735	.0556389	25
26	.0414435	.0436269	.0458847	.0482180	.0506279	.0531156	.0556823	26
27	.0414793	.0436640	.0459230	.0482575	.0506687	.0531578	.0557258	27
28	.0415151	.0437010	.0459613	.0482971	.0507096	.0531999	.0557692	28
29	.0415509	.0437381	.0459996	.0483367	.0507504	.0532421	.0558127	29
30	.0415868	.0437751	.0460379	.0483763	.0507913	.0532843	.0558563	30
31	.0416227	.0438122	.0460763	.0484159	.0508322	.0533265	.0558998	31
32	.0416585	.0438494	.0461146	.0484555	.0508732	.0533687	.0559434	32
33	.0416944	.0438865	.0461530	.0484952	.0509141	.0534110	.0559869	33
34	.0417304	.0439237	.0461914	.0485349	.0509551	.0534533	.0560305	34
35	.0417663	.0439608	.0462299	.0485746	.0509961	.0534956	.0560742	35
36	.0418023	.0439980	.0462683	.0486143	.0510371	.0535379	.0561178	36
37	.0418383	.0440353	.0463068	.0486540	.0510782	.0535802	.0561615	37
38	.0418743	.0440725	.0463453	.0486938	.0511192	.0536226	.0562052	38
39	.0419103	.0441098	.0463838	.0487336	.0511603	.0536650	.0562489	39
40	.0419464	.0441471	.0464223	.0487734	.0512014	.0537074	.0562926	40
41	.0419825	.0441844	.0464609	.0488132	.0512425	.0537499	.0563364	41
42	.0420185	.0442217	.0464995	.0488531	.0512837	.0537923	.0563802	42
43	.0420547	.0442591	.0465381	.0488929	.0513248	.0538348	.0564240	43
44	.0420908	.0442964	.0465767	.0489328	.0513660	.0538773	.0564678	44
45	.0421269	.0443338	.0466154	.0489728	.0514072	.0539198	.0565117	45
46	.0421631	.0443712	.0466540	.0490127	.0514484	.0539624	.0565556	46
47	.0421993	.0444087	.0466927	.0490527	.0514897	.0540049	.0565995	47
48	.0422355	.0444461	.0467314	.0490926	.0515310	.0540475	.0566434	48
49	.0422718	.0444836	.0467702	.0491326	.0515723	.0540901	.0566873	49
50	.0423080	.0445211	.0468089	.0491727	.0516136	.0541328	.0567313	50
51	.0423443	.0445586	.0468477	.0492127	.0516549	.0541754	.0567753	51
52	.0423806	.0445961	.0468865	.0492528	.0516963	.0542181	.0568193	52
53	.0424169	.0446337	.0469253	.0492929	.0517377	.0542608	.0568633	53
54	.0424533	.0446712	.0469641	.0493330	.0517791	.0543035	.0569074	54
55	.0424896	.0447088	.0470030	.0493732	.0518205	.0543462	.0569515	55
56	.0425260	.0447465	.0470418	.0494133	.0518620	.0543890	.0569956	56
57	.0425624	.0447841	.0470807	.0494535	.0519034	.0544318	.0570397	57
58	.0425988	.0448218	.0471196	.0494937	.0519449	.0544746	.0570838	58
59	.0426353	.0448594	.0471586	.0495339	.0519865	.0545174	.0571280	59
60	.0426717	.0448971	.0471975	.0495742	.0520280	.0545603	.0571722	60

Mln.	64°	65°	66°	67°	68°	69°	70°	Mln.
	Diff. 442	Diff. 456	Diff. 469	Diff. 483	Diff. 497	Diff. 512	Diff. 526	
0	.0571722	.0598648	.0626393	.0654966	.0684381	.0714647	.0745776	0
1	.0572164	.0599104	.0626862	.0655450	.0684878	.0715159	.0746302	1
2	.0572606	.0599559	.0627332	.0655933	.0685376	.0715671	.0746828	2
3	.0573049	.0600016	.0627802	.0656417	.0685874	.0716183	.0747355	3
4	.0573492	.0600472	.0628272	.0656901	.0686372	.0716696	.0747882	4
5	.0573935	.0600929	.0628742	.0657385	.0686871	.0717208	.0748409	5
6	.0574378	.0601385	.0629212	.0657870	.0687369	.0717721	.0748937	6
7	.0574822	.0601842	.0629683	.0658354	.0687868	.0718234	.0749464	7
8	.0575265	.0602300	.0630154	.0658839	.0688367	.0718748	.0749992	8
9	.0575709	.0602757	.0630625	.0659324	.0688866	.0719261	.0750520	9
10	.0576153	.0603215	.0631097	.0659810	.0689366	.0719775	.0751049	10
11	.0576598	.0603673	.0631568	.0660296	.0689866	.0720289	.0751577	11
12	.0577042	.0604131	.0632040	.0660781	.0690366	.0720804	.0752106	12
13	.0577487	.0604590	.0632512	.0661268	.0690866	.0721318	.0752635	13
14	.0577932	.0605048	.0632985	.0661754	.0691367	.0721833	.0753165	14
15	.0578377	.0605507	.0633457	.0662241	.0691867	.0722348	.0753694	15
16	.0578823	.0605966	.0633930	.0662727	.0692368	.0722864	.0754224	16
17	.0579268	.0606425	.0634403	.0663215	.0692870	.0723379	.0754754	17
18	.0579714	.0606885	.0634877	.0663702	.0693371	.0723895	.0755284	18
19	.0580160	.0607345	.0635350	.0664189	.0693873	.0724411	.0755815	19
20	.0580607	.0607805	.0635824	.0664677	.0694375	.0724927	.0756346	20
21	.0581054	.0608265	.0636298	.0665165	.0694877	.0725444	.0756877	21
22	.0581500	.0608725	.0636772	.0665653	.0695379	.0725960	.0757408	22
23	.0581948	.0609186	.0637247	.0666142	.0695882	.0726478	.0757940	23
24	.0582395	.0609647	.0637722	.0666630	.0696385	.0726995	.0758472	24
25	.0582843	.0610108	.0638196	.0667119	.0696888	.0727512	.0759004	25
26	.0583290	.0610569	.0638672	.0667609	.0697391	.0728030	.0759536	26
27	.0583738	.0611031	.0639147	.0668098	.0697895	.0728548	.0760068	27
28	.0584187	.0611493	.0639623	.0668588	.0698399	.0729066	.0760601	28
29	.0584635	.0611955	.0640099	.0669078	.0698903	.0729584	.0761134	29
30	.0585084	.0612417	.0640575	.0669568	.0699407	.0730103	.0761667	30
31	.0585532	.0612880	.0641051	.0670058	.0699912	.0730622	.0762201	31
32	.0585982	.0613342	.0641528	.0670549	.0700416	.0731141	.0762735	32
33	.0586431	.0613805	.0642004	.0671040	.0700921	.0731661	.0763269	33
34	.0586880	.0614269	.0642481	.0671531	.0701427	.0732180	.0763803	34
35	.0587330	.0614732	.0642959	.0672022	.0701932	.0732700	.0764337	35
36	.0587780	.0615196	.0643436	.0672513	.0702438	.0733220	.0764872	36
37	.0588230	.0615659	.0643914	.0673005	.0702944	.0733741	.0765407	37
38	.0588681	.0616124	.0644392	.0673497	.0703450	.0734261	.0765942	38
39	.0589131	.0616588	.0644870	.0673989	.0703956	.0734782	.0766477	39
40	.0589582	.0617052	.0645349	.0674482	.0704463	.0735303	.0767013	40
41	.0590033	.0617517	.0645827	.0674975	.0704970	.0735825	.0767549	41
42	.0590485	.0617982	.0646306	.0675468	.0705477	.0736346	.0768085	42
43	.0590936	.0618448	.0646786	.0675961	.0705985	.0736868	.0768622	43
44	.0591388	.0618913	.0647265	.0676454	.0706492	.0737390	.0769158	44
45	.0591840	.0619379	.0647745	.0676948	.0707000	.0737912	.0769695	45
46	.0592292	.0619845	.0648224	.0677442	.0707508	.0738435	.0770232	46
47	.0592745	.0620311	.0648705	.0677936	.0708017	.0738958	.0770770	47
48	.0593197	.0620777	.0649185	.0678430	.0708525	.0739481	.0771307	48
49	.0593650	.0621244	.0649665	.0678925	.0709034	.0740004	.0771845	49
50	.0594104	.0621711	.0650146	.0679419	.0709543	.0740528	.0772383	50
51	.0594557	.0622178	.0650627	.0679914	.0710053	.0741051	.0772922	51
52	.0595011	.0622645	.0651108	.0680410	.0710562	.0741575	.0773460	52
53	.0595465	.0623113	.0651590	.0680905	.0711072	.0742099	.0773999	53
54	.0595919	.0623581	.0652071	.0681401	.0711582	.0742624	.0774538	54
55	.0596373	.0624049	.0652553	.0681897	.0712092	.0743149	.0775077	55
56	.0596827	.0624517	.0653035	.0682393	.0712603	.0743674	.0775617	56
57	.0597282	.0624986	.0653518	.0682890	.0713114	.0744199	.0776157	57
58	.0597737	.0625454	.0654001	.0683387	.0713625	.0744724	.0776697	58
59	.0598192	.0625923	.0654483	.0683884	.0714136	.0745250	.0777237	59
60	.0598648	.0626393	.0654966	.0684381	.0714647	.0745776	.0777778	60

Min.	71°	72°	73°	74°	75°	76°	77°	Min.
	Diff. 541	Diff. 555	Diff. 570	Diff. 586	Diff. 601	Diff. 617	Diff. 633	
0	.0777778	.0810665	.0844448	.0879136	.0914741	.0951273	.0988742	0
1	.0778319	.0811221	.0845018	.0879722	.0915342	.0951890	.0989375	1
2	.0778861	.0811777	.0845589	.0880308	.0915943	.0952507	.0990008	2
3	.0779402	.0812333	.0846160	.0880894	.0916545	.0953124	.0990641	3
4	.0779943	.0812890	.0846732	.0881481	.0917147	.0953742	.0991274	4
5	.0780485	.0813446	.0847303	.0882067	.0917749	.0954359	.0991907	5
6	.0781027	.0814003	.0847875	.0882654	.0918352	.0954977	.0992541	6
7	.0781570	.0814560	.0848447	.0883242	.0918954	.0955596	.0993175	7
8	.0782112	.0815118	.0849019	.0883829	.0919557	.0956214	.0993810	8
9	.0782655	.0815675	.0849592	.0884417	.0920161	.0956833	.0994444	9
10	.0783198	.0816233	.0850166	.0885006	.0920764	.0957452	.0995079	10
11	.0783741	.0816792	.0850739	.0885595	.0921368	.0958072	.0995714	11
12	.0784285	.0817350	.0851312	.0886183	.0921972	.0958691	.0996350	12
13	.0784829	.0817909	.0851886	.0886772	.0922576	.0959311	.0996985	13
14	.0785373	.0818467	.0852460	.0887361	.0923181	.0959932	.0997621	14
15	.0785917	.0819027	.0853034	.0887950	.0923786	.0960552	.0998257	15
16	.0786462	.0819586	.0853608	.0888540	.0924391	.0961173	.0998894	16
17	.0787006	.0820146	.0854183	.0889130	.0924996	.0961794	.0999530	17
18	.0787552	.0820705	.0854758	.0889720	.0925602	.0962415	.1000167	18
19	.0788097	.0821266	.0855333	.0890310	.0926208	.0963037	.1000805	19
20	.0788642	.0821826	.0855909	.0890902	.0926814	.0963658	.1001442	20
21	.0789188	.0822387	.0856485	.0891493	.0927421	.0964280	.1002080	21
22	.0789734	.0822947	.0857061	.0892084	.0928028	.0964903	.1002718	22
23	.0790280	.0823509	.0857637	.0892675	.0928635	.0965525	.1003356	23
24	.0790827	.0824070	.0858213	.0893267	.0929242	.0966148	.1003994	24
25	.0791374	.0824632	.0858790	.0893859	.0929849	.0966771	.1004633	25
26	.0791921	.0825193	.0859367	.0894451	.0930457	.0967395	.1005273	26
27	.0792468	.0825756	.0859944	.0895044	.0931065	.0968018	.1005912	27
28	.0793015	.0826318	.0860521	.0895636	.0931673	.0968642	.1006552	28
29	.0793563	.0826881	.0861099	.0896229	.0932281	.0969266	.1007192	29
30	.0794111	.0827444	.0861678	.0896823	.0932890	.0969889	.1007832	30
31	.0794659	.0828007	.0862256	.0897417	.0933499	.0970514	.1008473	31
32	.0795208	.0828571	.0862834	.0898010	.0934108	.0971139	.1009113	32
33	.0795756	.0829134	.0863413	.0898604	.0934718	.0971764	.1009754	33
34	.0796305	.0829698	.0863992	.0899198	.0935328	.0972390	.1010396	34
35	.0796855	.0830262	.0864571	.0899793	.0935938	.0973015	.1011037	35
36	.0797404	.0830827	.0865151	.0900388	.0936548	.0973641	.1011679	36
37	.0797954	.0831391	.0865730	.0900983	.0937158	.0974268	.1012321	37
38	.0798504	.0831956	.0866310	.0901578	.0937769	.0974894	.1012963	38
39	.0799054	.0832521	.0866890	.0902173	.0938380	.0975521	.1013605	39
40	.0799604	.0833087	.0867472	.0902770	.0938992	.0976148	.1014248	40
41	.0800155	.0833653	.0868053	.0903366	.0939603	.0976775	.1014891	41
42	.0800706	.0834219	.0868634	.0903962	.0940215	.0977403	.1015535	42
43	.0801257	.0834785	.0869215	.0904559	.0940827	.0978031	.1016178	43
44	.0801809	.0835351	.0869796	.0905156	.0941440	.0978659	.1016822	44
45	.0802360	.0835918	.0870378	.0905753	.0942052	.0979287	.1017466	45
46	.0802912	.0836485	.0870960	.0906350	.0942665	.0979916	.1018111	46
47	.0803464	.0837052	.0871542	.0906947	.0943278	.0980544	.1018755	47
48	.0804017	.0837619	.0872124	.0907545	.0943892	.0981174	.1019400	48
49	.0804569	.0838187	.0872707	.0908143	.0944505	.0981803	.1020045	49
50	.0805123	.0838755	.0873291	.0908742	.0945119	.0982432	.1020691	50
51	.0805676	.0839323	.0873874	.0909341	.0945734	.0983062	.1021337	51
52	.0806229	.0839891	.0874458	.0909940	.0946348	.0983692	.1021983	52
53	.0806783	.0840460	.0875042	.0910539	.0946963	.0984323	.1022629	53
54	.0807337	.0841029	.0875626	.0911138	.0947578	.0984953	.1023276	54
55	.0807891	.0841598	.0876210	.0911738	.0948193	.0985584	.1023922	55
56	.0808445	.0842167	.0876794	.0912338	.0948808	.0986216	.1024569	56
57	.0809000	.0842737	.0877379	.0912938	.0949424	.0986847	.1025216	57
58	.0809555	.0843306	.0877964	.0913538	.0950040	.0987479	.1025864	58
59	.0810110	.0843877	.0878549	.0914139	.0950656	.0988111	.1026512	59
60	.0810665	.0844448	.0879136	.0914741	.0951273	.0988742	.1027160	60

Min.	78°	79°	80°	81°	82°	83°	84°	Min.
	Diff. 649	Diff. 664	Diff. 681	Diff. 697	Diff. 714	Diff. 730	Diff. 747	
0	.1027160	.1066537	.1106882	.1148206	.1190519	.1233832	.1278154	0
1	.1027809	.1067201	.1107563	.1148903	.1191233	.1234562	.1278901	1
2	.1028457	.1067866	.1108243	.1149601	.1191947	.1235293	.1279648	2
3	.1029106	.1068531	.1108925	.1150298	.1192661	.1236024	.1280396	3
4	.1029756	.1069196	.1109606	.1150996	.1193375	.1236755	.1281144	4
5	.1030405	.1069862	.1110288	.1151694	.1194090	.1237486	.1281892	5
6	.1031055	.1070528	.1110970	.1152393	.1194805	.1238218	.1282641	6
7	.1031705	.1071194	.1111652	.1153091	.1195520	.1238950	.1283390	7
8	.1032355	.1071860	.1112335	.1153790	.1196236	.1239683	.1284139	8
9	.1033006	.1072527	.1113018	.1154490	.1196952	.1240415	.1284889	9
10	.1033656	.1073193	.1113701	.1155189	.1197668	.1241148	.1285639	10
11	.1034307	.1073860	.1114384	.1155889	.1198385	.1241881	.1286389	11
12	.1034959	.1074528	.1115068	.1156589	.1199101	.1242615	.1287140	12
13	.1035610	.1075196	.1115752	.1157290	.1199818	.1243349	.1287890	13
14	.1036262	.1075864	.1116436	.1157990	.1200536	.1244083	.1288641	14
15	.1036914	.1076532	.1117121	.1158691	.1201253	.1244817	.1289393	15
16	.1037567	.1077200	.1117805	.1159393	.1201971	.1245551	.1290144	16
17	.1038219	.1077869	.1118491	.1160094	.1202689	.1246286	.1290896	17
18	.1038872	.1078538	.1119176	.1160796	.1203407	.1247021	.1291648	18
19	.1039526	.1079208	.1119861	.1161498	.1204126	.1247757	.1292400	19
20	.1040179	.1079877	.1120547	.1162200	.1204845	.1248493	.1293154	20
21	.1040833	.1080547	.1121233	.1162903	.1205564	.1249229	.1293907	21
22	.1041487	.1081217	.1121920	.1163605	.1206284	.1249965	.1294660	22
23	.1042141	.1081887	.1122606	.1164308	.1207003	.1250702	.1295413	23
24	.1042795	.1082558	.1123294	.1165012	.1207723	.1251439	.1296167	24
25	.1043450	.1083229	.1123981	.1165715	.1208444	.1252176	.1296922	25
26	.1044105	.1083900	.1124668	.1166419	.1209164	.1252913	.1297676	26
27	.1044761	.1084572	.1125356	.1167123	.1209885	.1253651	.1298430	27
28	.1045416	.1085243	.1126044	.1167828	.1210606	.1254389	.1299185	28
29	.1046072	.1085915	.1126733	.1168532	.1211328	.1255127	.1299940	29
30	.1046728	.1086587	.1127421	.1169238	.1212050	.1255866	.1300696	30
31	.1047384	.1087260	.1128110	.1169944	.1212772	.1256605	.1301452	31
32	.1048041	.1087933	.1128799	.1170649	.1213494	.1257344	.1302208	32
33	.1048698	.1088606	.1129489	.1171355	.1214217	.1258083	.1302964	33
34	.1049355	.1089279	.1130178	.1172061	.1214939	.1258823	.1303721	34
35	.1050013	.1089953	.1130868	.1172768	.1215662	.1259563	.1304478	35
36	.1050670	.1090627	.1131559	.1173474	.1216386	.1260303	.1305235	36
37	.1051328	.1091301	.1132249	.1174181	.1217109	.1261043	.1305993	37
38	.1051987	.1091976	.1132940	.1174889	.1217833	.1261784	.1306750	38
39	.1052645	.1092650	.1133631	.1175596	.1218557	.1262525	.1307509	39
40	.1053304	.1093325	.1134322	.1176304	.1219283	.1263267	.1308267	40
41	.1053963	.1094000	.1135013	.1177012	.1220008	.1264008	.1309026	41
42	.1054622	.1094676	.1135705	.1177721	.1220733	.1264750	.1309785	42
43	.1055282	.1095352	.1136398	.1178429	.1221458	.1265492	.1310544	43
44	.1055942	.1096028	.1137090	.1179138	.1222183	.1266235	.1311303	44
45	.1056602	.1096704	.1137783	.1179847	.1222909	.1266977	.1312063	45
46	.1057263	.1097381	.1138476	.1180557	.1223635	.1267720	.1312823	46
47	.1057923	.1098058	.1139169	.1181267	.1224362	.1268464	.1313584	47
48	.1058584	.1098735	.1139863	.1181977	.1225088	.1269207	.1314344	48
49	.1059245	.1099412	.1140556	.1182687	.1225815	.1269951	.1315105	49
50	.1059907	.1100090	.1141250	.1183398	.1226543	.1270696	.1315866	50
51	.1060569	.1100768	.1141944	.1184109	.1227271	.1271441	.1316628	51
52	.1061231	.1101446	.1142639	.1184820	.1227999	.1272185	.1317390	52
53	.1061893	.1102125	.1143334	.1185532	.1228727	.1272930	.1318152	53
54	.1062556	.1102803	.1144029	.1186243	.1229455	.1273675	.1318914	54
55	.1063219	.1103483	.1144725	.1186955	.1230183	.1274421	.1319677	55
56	.1063882	.1104162	.1145420	.1187668	.1230912	.1275167	.1320440	56
57	.1064545	.1104841	.1146116	.1188380	.1231641	.1275913	.1321203	57
58	.1065209	.1105521	.1146813	.1189093	.1232371	.1276659	.1321967	58
59	.1065873	.1106201	.1147509	.1189806	.1233102	.1277407	.1322730	59
60	.1066537	.1106882	.1148206	.1190519	.1233832	.1278154	.1323494	60

Min.	85°	86°	87°	88°	89°	90°	91°	Min.
	Diff. 764	Diff. 782	Diff. 799	Diff. 817	Diff. 834	Diff. 852	Diff. 870	
0	.1323494	.1369864	.1417273	.1465730	.1515245	.1565828	.1617487	0
1	.1324259	.1370646	.1418072	.1466547	.1516080	.1566680	.1618357	1
2	.1325023	.1371428	.1418871	.1467363	.1516914	.1567532	.1619228	2
3	.1325788	.1372210	.1419670	.1468180	.1517749	.1568385	.1620098	3
4	.1326553	.1372993	.1420470	.1468998	.1518584	.1569238	.1620969	4
5	.1327319	.1373775	.1421270	.1469816	.1519420	.1570091	.1621840	5
6	.1328084	.1374558	.1422071	.1470634	.1520255	.1570945	.1622712	6
7	.1328850	.1375342	.1422871	.1471452	.1521092	.1571799	.1623584	7
8	.1329617	.1376125	.1423672	.1472270	.1521928	.1572653	.1624456	8
9	.1330383	.1376909	.1424474	.1473089	.1522765	.1573507	.1625328	9
10	.1331151	.1377693	.1425276	.1473909	.1523601	.1574363	.1626202	10
11	.1331918	.1378478	.1426078	.1474728	.1524439	.1575218	.1627076	11
12	.1332686	.1379263	.1426880	.1475548	.1525276	.1576073	.1627949	12
13	.1333453	.1380048	.1427683	.1476368	.1526114	.1576929	.1628823	13
14	.1334221	.1380833	.1428485	.1477188	.1526952	.1577785	.1629697	14
15	.1334990	.1381619	.1429288	.1478009	.1527791	.1578641	.1630571	15
16	.1335758	.1382405	.1430092	.1478830	.1528630	.1579498	.1631446	16
17	.1336527	.1383191	.1430895	.1479651	.1529469	.1580355	.1632320	17
18	.1337296	.1383978	.1431699	.1480473	.1530308	.1581212	.1633196	18
19	.1338066	.1384764	.1432503	.1481295	.1531147	.1582069	.1634071	19
20	.1338836	.1385551	.1433308	.1482117	.1531987	.1582927	.1634948	20
21	.1339606	.1386339	.1434113	.1482939	.1532827	.1583786	.1635824	21
22	.1340377	.1387127	.1434918	.1483762	.1533668	.1584644	.1636701	22
23	.1341147	.1387915	.1435724	.1484585	.1534508	.1585503	.1637577	23
24	.1341918	.1388703	.1436529	.1485408	.1535349	.1586362	.1638454	24
25	.1342689	.1389491	.1437335	.1486232	.1536191	.1587221	.1639332	25
26	.1343461	.1390280	.1438141	.1487056	.1537033	.1588081	.1640209	26
27	.1344232	.1391069	.1438948	.1487880	.1537875	.1588940	.1641087	27
28	.1345004	.1391859	.1439755	.1488705	.1538717	.1589801	.1641965	28
29	.1345777	.1392648	.1440562	.1489529	.1539559	.1590661	.1642844	29
30	.1346550	.1393438	.1441370	.1490355	.1540402	.1591522	.1643724	30
31	.1347323	.1394229	.1442178	.1491180	.1541246	.1592383	.1644603	31
32	.1348096	.1395019	.1442986	.1492006	.1542089	.1593245	.1645483	32
33	.1348870	.1395810	.1443794	.1492832	.1542933	.1594106	.1646363	33
34	.1349644	.1396601	.1444602	.1493658	.1543777	.1594968	.1647243	34
35	.1350418	.1397393	.1445411	.1494485	.1544621	.1595831	.1648123	35
36	.1351192	.1398184	.1446220	.1495312	.1545466	.1596693	.1649004	36
37	.1351967	.1398976	.1447030	.1496139	.1546311	.1597556	.1649885	37
38	.1352741	.1399769	.1447840	.1496966	.1547156	.1598419	.1650766	38
39	.1353517	.1400561	.1448650	.1497794	.1548002	.1599283	.1651648	39
40	.1354293	.1401354	.1449461	.1498622	.1548848	.1600147	.1652530	40
41	.1355069	.1402147	.1450271	.1499450	.1549694	.1601011	.1653412	41
42	.1355845	.1402941	.1451082	.1500279	.1550540	.1601876	.1654295	42
43	.1356621	.1403735	.1451893	.1501108	.1551387	.1602740	.1655178	43
44	.1357398	.1404529	.1452705	.1501937	.1552234	.1603605	.1656061	44
45	.1358175	.1405323	.1453517	.1502767	.1553082	.1604471	.1656944	45
46	.1358952	.1406118	.1454329	.1503597	.1553929	.1605336	.1657828	46
47	.1359729	.1406913	.1455141	.1504427	.1554777	.1606202	.1658712	47
48	.1360507	.1407708	.1455954	.1505258	.1555626	.1607068	.1659596	48
49	.1361285	.1408503	.1456767	.1506088	.1556474	.1607935	.1660481	49
50	.1362064	.1409299	.1457581	.1506918	.1557323	.1608802	.1661366	50
51	.1362843	.1410095	.1458394	.1507750	.1558172	.1609669	.1662252	51
52	.1363622	.1410892	.1459208	.1508581	.1559021	.1610537	.1663137	52
53	.1364401	.1411688	.1460022	.1509413	.1559871	.1611404	.1664023	53
54	.1365180	.1412485	.1460836	.1510245	.1560721	.1612272	.1664909	54
55	.1365960	.1413283	.1461651	.1511078	.1561571	.1613140	.1665796	55
56	.1366740	.1414080	.1462466	.1511911	.1562422	.1614009	.1666683	56
57	.1367521	.1414878	.1463281	.1512744	.1563273	.1614878	.1667570	57
58	.1368301	.1415676	.1464097	.1513577	.1564124	.1615747	.1668457	58
59	.1369083	.1416474	.1464914	.1514411	.1564976	.1616616	.1669345	59
60	.1369864	.1417273	.1465730	.1515245	.1565828	.1617487	.1670233	60

'	0°	10°	15°	20°	30°	40°	45°	50°	'
0	.00000	.00278	.00417	.00556	.00833	.01111	.01250	.01389	0
1	.01667	.01944	.02083	.02222	.02500	.02778	.02917	.03056	1
2	.03333	.03611	.03750	.03889	.04167	.04444	.04583	.04722	2
3	.05000	.05278	.05417	.05556	.05833	.06111	.06250	.06389	3
4	.06667	.06944	.07083	.07222	.07500	.07778	.07917	.08056	4
5	.08333	.08611	.08750	.08889	.09167	.09444	.09583	.09722	5
6	.10000	.10278	.10417	.10556	.10833	.11111	.11250	.11389	6
7	.11667	.11944	.12083	.12222	.12500	.12778	.12917	.13056	7
8	.13333	.13611	.13750	.13889	.14167	.14444	.14583	.14722	8
9	.15000	.15278	.15417	.15556	.15833	.16111	.16250	.16389	9
10	.16667	.16944	.17083	.17222	.17500	.17778	.17917	.18056	10
11	.18333	.18611	.18750	.18889	.19167	.19444	.19583	.19722	11
12	.20000	.20278	.20417	.20556	.20833	.21111	.21250	.21389	12
13	.21667	.21944	.22083	.22222	.22500	.22778	.22917	.23056	13
14	.23333	.23611	.23750	.23889	.24167	.24444	.24583	.24722	14
15	.25000	.25278	.25417	.25556	.25833	.26111	.26250	.26389	15
16	.26667	.26944	.27083	.27222	.27500	.27778	.27917	.28056	16
17	.28333	.28611	.28750	.28889	.29167	.29444	.29583	.29722	17
18	.30000	.30278	.30417	.30556	.30833	.31111	.31250	.31389	18
19	.31667	.31944	.32083	.32222	.32500	.32778	.32917	.33056	19
20	.33333	.33611	.33750	.33889	.34167	.34444	.34583	.34722	20
21	.35000	.35278	.35417	.35556	.35833	.36111	.36250	.36389	21
22	.36667	.36944	.37083	.37222	.37500	.37778	.37917	.38056	22
23	.38333	.38611	.38750	.38889	.39167	.39444	.39583	.39722	23
24	.40000	.40278	.40417	.40556	.40833	.41111	.41250	.41389	24
25	.41667	.41944	.42083	.42222	.42500	.42778	.42917	.43056	25
26	.43333	.43611	.43750	.43889	.44167	.44444	.44583	.44722	26
27	.45000	.45278	.45417	.45556	.45833	.46111	.46250	.46389	27
28	.46667	.46944	.47083	.47222	.47500	.47778	.47917	.48056	28
29	.48333	.48611	.48750	.48889	.49167	.49444	.49583	.49722	29
30	.50000	.50278	.50417	.50556	.50833	.51111	.51250	.51389	30
31	.51667	.51944	.52083	.52222	.52500	.52778	.52917	.53056	31
32	.53333	.53611	.53750	.53889	.54167	.54444	.54583	.54722	32
33	.55000	.55278	.55417	.55556	.55833	.56111	.56250	.56389	33
34	.56667	.56944	.57083	.57222	.57500	.57778	.57917	.58056	34
35	.58333	.58611	.58750	.58889	.59167	.59444	.59583	.59722	35
36	.60000	.60278	.60417	.60556	.60833	.61111	.61250	.61389	36
37	.61667	.61944	.62083	.62222	.62500	.62778	.62917	.63056	37
38	.63333	.63611	.63750	.63889	.64167	.64444	.64583	.64722	38
39	.65000	.65278	.65417	.65556	.65833	.66111	.66250	.66389	39
40	.66667	.66944	.67083	.67222	.67500	.67778	.67917	.68056	40
41	.68333	.68611	.68750	.68889	.69167	.69444	.69583	.69722	41
42	.70000	.70278	.70417	.70556	.70833	.71111	.71250	.71389	42
43	.71667	.71944	.72083	.72222	.72500	.72778	.72917	.73056	43
44	.73333	.73611	.73750	.73889	.74167	.74444	.74583	.74722	44
45	.75000	.75278	.75417	.75556	.75833	.76111	.76250	.76389	45
46	.76667	.76944	.77083	.77222	.77500	.77778	.77917	.78056	46
47	.78333	.78611	.78750	.78889	.79167	.79444	.79583	.79722	47
48	.80000	.80278	.80417	.80556	.80833	.81111	.81250	.81389	48
49	.81667	.81944	.82083	.82222	.82500	.82778	.82917	.83056	49
50	.83333	.83611	.83750	.83889	.84167	.84444	.84583	.84722	50
51	.85000	.85278	.85417	.85556	.85833	.86111	.86250	.86389	51
52	.86667	.86944	.87083	.87222	.87500	.87778	.87917	.88056	52
53	.88333	.88611	.88750	.88889	.89167	.89444	.89583	.89722	53
54	.90000	.90278	.90417	.90556	.90833	.91111	.91250	.91389	54
55	.91667	.91944	.92083	.92222	.92500	.92778	.92917	.93056	55
56	.93333	.93611	.93750	.93889	.94167	.94444	.94583	.94722	56
57	.95000	.95278	.95417	.95556	.95833	.96111	.96250	.96389	57
58	.96667	.96944	.97083	.97222	.97500	.97778	.97917	.98056	58
59	.98333	.98611	.98750	.98889	.99167	.99444	.99583	.99722	59
'	0°	10°	15°	20°	30°	40°	45°	50°	'

TABLE XXII.—TURNOUTS AND SWITCHES FROM A STRAIGHT TRACK 59

GAUGE, 4 FEET 8½ INCHES = 4.708. THROW, 5 INCHES = 0.417.

No. <i>n.</i>	Angle <i>F.</i>	Dist. <i>BF.</i>	Chord <i>af.</i>	Switch <i>AD.</i>	Radius <i>r.</i>	Log'thm. <i>log. r.</i>	Degree of Curve.
4	14° 15' 00"	37.664	37.373	11.209	150.656	2.177986	38° 45' 57"
4½	12 40 49	42.372	42.113	12.610	190.674	2.280292	30 24 09
5	11 25 16	47.080	46.846	14.012	235.400	2.371806	24 31 36
5½	10 23 20	51.788	51.575	15.413	284.834	2.454592	20 13 13
6	9 31 38	56.496	56.301	16.814	338.976	2.530169	16 57 52
6½	8 47 51	61.204	61.024	18.215	397.826	2.599693	14 26 25
7	8 10 16	65.912	65.744	19.616	461.384	2.664063	12 26 34
7½	7 37 41	70.620	70.464	21.017	529.650	2.723989	10 50 02
8	7 09 10	75.328	75.181	22.418	602.624	2.780046	9 31 07
8½	6 43 59	80.036	79.898	23.820	680.306	2.832704	8 25 47
9	6 21 35	84.744	84.613	25.221	762.696	2.882352	7 31 04
9½	6 01 32	89.452	89.328	26.622	849.794	2.929314	6 44 46
10	5 43 29	94.160	94.043	28.023	941.600	2.973866	6 05 16
10½	5 27 09	98.868	98.756	29.424	1038.114	3.016245	5 31 17
11	5 12 18	103.576	103.469	30.825	1139.336	3.056652	5 01 50
11½	4 58 45	108.284	108.182	32.227	1245.266	3.095262	4 36 08
12	4 46 19	112.992	112.894	33.628	1355.904	3.132229	4 13 36

GAUGE, 3 FEET. THROW, 4 INCHES = 0.333.

No. <i>n.</i>	Angle <i>F.</i>	Dist. <i>BF.</i>	Chord <i>af.</i>	Switch <i>AD.</i>	Radius <i>r.</i>	Log'thm. <i>log. r.</i>	Degree of Curve.
4	14° 15' 00"	24	23.815	8	96.0	1.982271	62° 46' 34"
4½	12 40 49	27	26.835	9	121.5	2.084576	48 36 04
5	11 25 16	30	29.851	10	150.0	2.176091	38 56 33
5½	10 23 20	33	32.865	11	181.5	2.258877	31 58 55
6	9 31 38	36	35.876	12	216.0	2.334454	26 46 07
6½	8 47 51	39	38.885	13	253.5	2.403978	22 45 04
7	8 10 16	42	41.893	14	294.0	2.468347	19 35 01
7½	7 37 41	45	44.900	15	337.5	2.528274	17 02 21
8	7 09 10	48	47.906	16	384.0	2.584331	14 57 48
8½	6 43 59	51	50.912	17	433.5	2.636989	13 14 47
9	6 21 35	54	53.917	18	486.0	2.686636	11 48 37
9½	6 01 32	57	56.921	19	541.5	2.733598	10 35 46
10	5 43 29	60	59.925	20	600.0	2.778151	9 33 38
10½	5 27 09	63	62.929	21	661.5	2.820530	8 40 12
11	5 12 18	66	65.932	22	726.0	2.860937	7 53 54
11½	4 58 45	69	68.935	23	793.5	2.899547	7 13 32
12	4 46 19	72	71.938	24	864.0	2.936514	6 38 06

ANGLE AND DISTANCE OF MIDDLE FROG, *F"*

No. <i>n.</i>	No. <i>n.</i>	Angle <i>F"</i>	Gauge 4, 8½. Dist. <i>aF"</i>	Gauge 3. Dist. <i>aF"</i>	No. <i>n.</i>	No. <i>n.</i>	Angle <i>F"</i>	Gauge 4, 8½. Dist. <i>aF"</i>	Gauge 3. Dist. <i>aF"</i>
4	2.817	20° 07' 36"	26.736	17.037	8	5.651	10° 06' 44"	53.317	33.974
4½	3.172	17 54 52	30.064	19.151	8½	6.005	9 31 08	56.643	36.094
5	3.527	16 08 19	33.374	21.266	9	6.359	8 59 30	59.969	38.213
5½	3.881	14 40 58	36.695	23.385	9½	6.713	8 31 10	63.296	40.333
6	4.235	13 27 57	40.018	25.500	10	7.067	8 05 40	66.623	42.453
6½	4.589	12 26 07	43.342	27.618	10½	7.420	7 42 35	69.950	44.573
7	4.943	11 33 04	46.666	29.736	11	7.774	7 21 36	73.277	46.693
7½	5.297	10 47 02	49.991	31.855	11½	8.128	7 02 26	76.605	48.813
8	5.651	10 06 44	53.317	33.974	12	8.482	6 44 51	79.932	50.934

MISCELLANEOUS TURNOUT DATA

PROPERTIES OF FROGS										PROPERTIES OF SWITCHES			THEORETICAL LEADS For P.C. at Heel of Switch and P.T. at Toe End of Frog		
Frog Number	Frog Angle	Overall Length	½-in. Point		Heel Length to ½-in. Point	Toe Spread	Heel Spread	A.R.E.A. Plans of Frogs	Length of Switch Rail	Thickness of Point = ¼ in. Heel Spread = 6¼ in.		A.R.E.A. Plans of Switches	Radius of Center Line	Degree of Curve	Distance Point of Switch to ½-in. Point of Frog
										Switch Angle					
4	14° 15' 00"	9' 0"	3' 8½"	5' 3½"	109½"	161½"	271	11' 0"	2° 36' 19"	103-104	109.15'	54° 31' 38"	36.97'		
5	11° 25' 16"	10' 0"	3' 10"	6' 2"	81½"	151½"	272	11' 0"	2° 36' 19"	103-104	182.52'	31° 47' 52"	42.95'		
6	9° 31' 38"	11' 4½"	4' 6½"	6' 10"	89½"	141½"	273	11' 0"	2° 36' 19"	103-104	270.17'	21° 19' 49"	48.19'		
7	8° 10' 16"	14' 7½"	6' 2"	8' 5½"	104½"	141½"	274	16' 6"	1° 44' 11"	101-102	343.52'	16° 44' 20"	61.28'		
8	7° 09' 10"	15' 5"	6' 2"	9' 3"	83½"	143½"	275	16' 6"	1° 44' 11"	101-102	470.28'	12° 12' 24"	67.14'		
9	6° 21' 35"	16' 3"	6' 2"	10' 1"	71½"	131½"	276	16' 6"	1° 44' 11"	101-102	620.32'	9° 14' 47"	72.73'		
10	5° 43' 29"	17' 10½"	7' 0"	10' 10½"	77½"	139½"	277	16' 6"	1° 44' 11"	101-102	777.38'	7° 22' 32"	77.61'		
11	5° 12' 18"	18' 8½"	7' 0"	11' 8½"	71½"	131½"	278	22' 0"	1° 18' 08"	105-106	927.48'	6° 10' 50"	92.19'		
12	4° 46' 19"	20' 4"	7' 9½"	12' 6½"	75½"	131½"	279	22' 0"	1° 18' 08"	105-106	1113.88'	5° 08' 44"	97.25'		
14	4° 05' 27"	23' 7"	8' 7½"	14' 11½"	67½"	135½"	281	22' 0"	1° 18' 08"	105-106	1576.06'	3° 38' 10"	107.33'		
15	3° 49' 06"	24' 4½"	9' 5"	14' 11½"	7"	127½"	282	30' 0"	0° 57' 18"	107-108	1728.66'	3° 18' 54"	125.82'		
16	3° 34' 47"	26' 0"	9' 5"	16' 7"	69½"	121½"	283	30' 0"	0° 57' 18"	107-108	2036.92'	2° 51' 19"	131.36'		
18	3° 10' 56"	29' 3"	11' 0½"	18' 2½"	67½"	125½"	291	30' 0"	0° 57' 18"	107-108	2575.02'	2° 13' 31"	141.14'		
20	2° 51' 51"	30' 10½"	11' 0½"	19' 10"	67½"	123½"	292	30' 0"	0° 57' 18"	107-108	3309.76'	1° 43' 52"	151.32'		

NOTES

1.—*Turnouts and crossovers recommended*—For Main Line High Speed Movements, No. 16 or No. 20. For Main Line Slow Speed Movements, No. 12 or No. 10. For Yards and Sidings, to meet General Conditions, No. 8.

2.—*Gauge*—The *leads* shown are computed for the standard track gauge of 4'-8½". When conditions require a wider gauge than 4'-8½", the length lead as shown for 4'-8½" gauge shall be maintained and the gauge widened on the inside rail back of the heel of switch.

3.—*Scope of this plan*—The Turnout Tables are applicable for frogs and switches of the dimensions shown, and are subject to modification for other conditions.

4. *Alternates:*

- (a) Other combinations of closure rails may be used to equal the same length leads.
- (b) Modified frog lengths may be used and the lengths of the closure rails modified to correspond without change in alinement.
- (c) Switch rails with slightly modified angle (as for ¼" variation in heel spread) may be used with leads shown without appreciable change in alinement; but if the switch angle be changed markedly, then the lead and alinement should be recomputed to suit conditions.
- (d) For other notes relating to modified lengths and angles, see notes on frog and switch plans referred to in table.

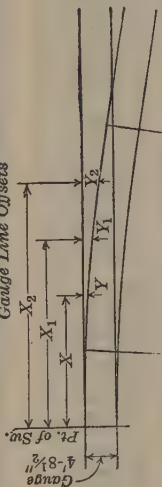
PRACTICAL TURNOUT LEADS

Frog Number	Length of Switch Rail	Lead = Actual Distance Point of Switch Rail to $\frac{1}{2}$ in. Point of Frog	CLOSURE RAILS Lengths in Feet and Inches		LEAD CURVE	
			Straight Rail	Curved Rail	Radius of Center Line	Degree of Curve
4 5	11' 0" 11' 0"	36' $11\frac{1}{2}$ " 42' 10"	22' 3" 28' 0"	22' 8" 28' $3\frac{3}{4}$ "	109.15' 180.49'	54° 31' 38" 32° 09' 56"
6 7	11' 0" 16' 6"	48' $31\frac{1}{2}$ " 61' 5"	32' 9" 38' 9"	33' 0" 39' 0"	269.54' 342.85'	21° 22' 52" 16° 46' 16"
8 9	16' 6" 16' 6"	67' 1" 72' 1"	28' 0" + 16' 5" 33' 0" + 16' 5"	28' 0" + 16' 7" 33' 0" + 16' 7"	468.64' 598.33'	12° 14' 58" 9° 35' 14"
10 11	16' 6" 22' 0"	77' 5" 91' $10\frac{1}{4}$ "	39' 0" + 14' 11" 39' 0" + 23' $10\frac{1}{4}$ "	39' 0" + 15' 1" 39' 0" + 24' 0"	769.40' 914.37'	7° 27' 07" 6° 16' 09"
12 14	22' 0" 22' 0"	96' 8" 107' $0\frac{3}{4}$ "	39' 0" + 27' $10\frac{1}{2}$ " 30' 0" + 30' 0" + 16' $5\frac{1}{4}$ "	39' 0" + 28' 0" 30' 0" + 30' 0" + 16' $6\frac{3}{4}$ "	1087.30' 1560.07'	5° 16' 17" 3° 40' 24"
15 16	30' 0" 30' 0"	126' $41\frac{1}{2}$ " 131' $\frac{1}{4}$ "	39' 0" + 33' 0" + 14' $11\frac{1}{2}$ " 33' 0" + 33' 0" + 25' 11"	39' 0" + 33' 0" + 15' $0\frac{1}{2}$ " 33' 0" + 33' 0" + 26' 0"	1721.17' 2005.33'	3° 19' 46" 2° 51' 27"
18 20	30' 0" 30' 0"	140' $11\frac{1}{2}$ " 151' $11\frac{1}{2}$ "	39' 0" + 33' 0" + 27' 11" 39' 0" + 39' 0" + 32' 11"	39' 0" + 33' 0" + 28' 0" 39' 0" + 39' 0" + 33' 0"	2561.77' 3290.64'	2° 14' 12" 1° 44' 28"

PRACTICAL TURNOUT LEADS—Continued

Frog Number.	Gauge Line Offsets						Tangent Adjacent to Switch Rail.	Tangent Adjacent to Toe of Frog.	A.R.E.A. Plans of Turnouts and Crossovers.
	x	x ₁	x ₂	y	y ₁	y ₂			
4	16' 6 3/4"	22' 1 1/2"	27' 8 1/4"	11"	19 1/16"	2' 6 9/16"	0.00'	0.00'	901
5	18' 0"	25' 0"	32' 0"	11 1/16"	20 3/8"	2' 8 3/8"	0.00'	0.19'	
6	19' 2 1/4"	27' 4 1/2"	35' 6 3/4"	12 1/8"	21"	2' 8 15/16"	0.18'	0.00'	902
7	26' 2 1/4"	35' 10 1/2"	45' 6 3/4"	11 5/16"	19 1/16"	2' 7 3/8"	0.21'	0.00'	
8	27' 7 1/4"	38' 8 1/2"	49' 9 3/4"	11 7/8"	20 5/8"	2' 8 9/16"	0.00'	0.10'	903
9	28' 10 1/4"	41' 2 1/2"	53' 6 3/4"	12 1/4"	21 3/8"	2' 9 1/2"	0.00'	1.13'	
10	29' 11 3/4"	43' 5 1/2"	56' 11 1/4"	12 9/16"	21 3/4"	2' 9 3/4"	0.00'	0.36'	904
11	37' 8 1/2"	53' 5"	69' 1 1/2"	12 3/16"	21 5/16"	2' 9 11/16"	0.00'	0.56'	
12	38' 8 1/2"	55' 5"	72' 1 1/2"	12 3/8"	21 9/16"	2' 9 13/16"	0.00'	1.02'	905
14	41' 1 1/4"	60' 2 1/2"	79' 3 3/4"	12 7/8"	22 5/16"	2' 10 1/2"	0.00'	0.51'	
15	51' 9"	73' 6"	95' 3"	12 1/8"	21 1/4"	2' 9 3/4"	0.93'	0.00'	907
16	53' 0"	76' 0"	99' 0"	12 1/16"	21 13/16"	2' 10 9/16"	0.00'	0.05'	
18	55' 0"	80' 0"	105' 0"	12 3/4"	22 1/8"	2' 10 7/16"	0.00'	0.33'	908
20	57' 9"	85' 6"	113' 3"	13 1/16"	22 3/4"	2' 11 3/16"	1.27'	0.00'	

Gauge Line Offsets



No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
1	1	1	1.0000000	1.0000000	1.000000000
2	4	8	1.4142136	1.2599210	.500000000
3	9	27	1.7320508	1.4422496	.333333333
4	16	64	2.0000000	1.5874011	.250000000
5	25	125	2.2360680	1.7099759	.200000000
6	36	216	2.4494897	1.8171206	.166666667
7	49	343	2.6457513	1.9129312	.142857143
8	64	512	2.8284271	2.0000000	.125000000
9	81	729	3.0000000	2.0800837	.111111111
10	100	1000	3.1622777	2.1544347	.100000000
11	121	1331	3.3166248	2.2239801	.090909091
12	144	1728	3.4641016	2.2594286	.083333333
13	169	2197	3.6055513	2.3513347	.076923077
14	196	2744	3.7416574	2.4101422	.071428571
15	225	3375	3.8729833	2.4662121	.066666667
16	256	4096	4.0000000	2.5198421	.062500000
17	289	4913	4.1231056	2.5712816	.058823529
18	324	5832	4.2426407	2.6207414	.055555556
19	361	6859	4.3588989	2.6684016	.052631579
20	400	8000	4.4721360	2.7144177	.050000000
21	441	9261	4.5825757	2.7589243	.047619048
22	484	10648	4.6904158	2.8020393	.045454545
23	529	12167	4.7958315	2.8438670	.043478261
24	576	13824	4.8989795	2.8844991	.041666667
25	625	15625	5.0000000	2.9240177	.040000000
26	676	17576	5.0990195	2.9624960	.038461538
27	729	19683	5.1961524	3.0000000	.037037037
28	784	21952	5.2915026	3.0365889	.035714286
29	841	24389	5.3851648	3.0723168	.034482759
30	900	27000	5.4772256	3.1072325	.033333333
31	961	29791	5.5677644	3.1413806	.032258065
32	1024	32768	5.6568542	3.1748021	.031250000
33	1089	35937	5.7445626	3.2075343	.030303030
34	1156	39304	5.8309519	3.2396118	.029411765
35	1225	42875	5.9160798	3.2710663	.028571429
36	1296	46656	6.0000000	3.3019272	.027777778
37	1369	50653	6.0827625	3.3322218	.027027027
38	1444	54872	6.1641140	3.3619754	.026315789
39	1521	59319	6.2449980	3.3912114	.025641026
40	1600	64000	6.3245553	3.4199519	.025000000
41	1681	68921	6.4031242	3.4482172	.024390244
42	1764	74088	6.4807407	3.4760266	.023809524
43	1849	79507	6.5574385	3.5033981	.023255814
44	1936	85184	6.6332496	3.5303483	.022727273
45	2025	91125	6.7082039	3.5568933	.022222222
46	2116	97336	6.7823300	3.5830479	.021739130
47	2209	103823	6.8556546	3.6088261	.021276596
48	2304	110592	6.9282032	3.6342411	.020833333
49	2401	117649	7.0000000	3.6593057	.020408163
50	2500	125000	7.0710678	3.6840314	.020000000
51	2601	132651	7.1414284	3.7084298	.019607843
52	2704	140608	7.2111026	3.7325111	.019230769
53	2809	148877	7.2801099	3.7562858	.018867925
54	2916	157464	7.3484692	3.7797631	.018518519
55	3025	166375	7.4161985	3.8029525	.018181818
56	3136	175616	7.4833148	3.8258624	.017857143
57	3249	185193	7.5498344	3.8485011	.017543860
58	3364	195112	7.6157731	3.8708766	.017241379
59	3481	205379	7.6811457	3.8929965	.016949153
60	3600	216000	7.7459667	3.9148676	.016666667
61	3721	226981	7.8102497	3.9364972	.016393443
62	3844	238328	7.8740079	3.9578915	.016129032

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
63	3969	250047	7.9372539	3.9790571	.015873016
64	4096	262144	8.0000000	4.0000000	.015625000
65	4225	274625	8.0622577	4.0207256	.015384615
66	4356	287496	8.1240384	4.0412401	.015151515
67	4489	300763	8.1853528	4.0615480	.014925373
68	4624	314432	8.2462113	4.0816551	.014705882
69	4761	328509	8.3066239	4.1015661	.014492754
70	4900	343000	8.3666003	4.1212853	.014285714
71	5041	357911	8.4261498	4.1408178	.014084507
72	5184	373248	8.4852814	4.1601676	.013888889
73	5329	389017	8.5440037	4.1793390	.013698630
74	5476	405224	8.6023253	4.1983364	.013513514
75	5625	421875	8.6602540	4.2171633	.013333333
76	5776	438976	8.7177979	4.2358236	.013157895
77	5929	456533	8.7749644	4.2543210	.012987013
78	6084	474552	8.8317609	4.2726586	.012820513
79	6241	493039	8.8881944	4.2908404	.012658228
80	6400	512000	8.9442719	4.3088695	.012500000
81	6561	531441	9.0000000	4.3267487	.012345679
82	6724	551368	9.0553851	4.3444815	.012195122
83	6889	571787	9.1104336	4.3620707	.012048193
84	7056	592704	9.1651514	4.3795191	.011904762
85	7225	614125	9.2195445	4.3968296	.011764706
86	7396	636056	9.2736185	4.4140049	.011627907
87	7569	658503	9.3273791	4.4310476	.011494253
88	7744	681472	9.3808315	4.4479602	.011363636
89	7921	704969	9.4339811	4.4647451	.011235955
90	8100	729000	9.4868330	4.4814047	.011111111
91	8281	753571	9.5393920	4.4979414	.010989011
92	8464	778688	9.5916630	4.5143574	.010869565
93	8649	804357	9.6436508	4.5306549	.010752688
94	8836	830584	9.6953597	4.5468359	.010638298
95	9025	857375	9.7467943	4.5629026	.010526316
96	9216	884736	9.7979590	4.5788570	.010416667
97	9409	912673	9.8488578	4.5947009	.010309278
98	9604	941192	9.8994949	4.6104363	.010204082
99	9801	970299	9.9498744	4.6260650	.010101010
100	10000	1000000	10.0000000	4.6415888	.010000000
101	10201	1030301	10.0498756	4.6570095	.009900990
102	10404	1061208	10.0995049	4.6723287	.009803922
103	10609	1092727	10.1488916	4.6875482	.009708738
104	10816	1124864	10.1980390	4.7026694	.009615385
105	11025	1157625	10.2469508	4.7176940	.009523810
106	11236	1191016	10.2956301	4.7326235	.009433962
107	11449	1225043	10.3440804	4.7474594	.009345794
108	11664	1259712	10.3923048	4.7622032	.009259259
109	11881	1295029	10.4403065	4.7768562	.009174312
110	12100	1331000	10.4880985	4.7914199	.009090909
111	12321	1367631	10.5356538	4.8058955	.009009009
112	12544	1404928	10.5830052	4.8202845	.008928571
113	12769	1442897	10.6301458	4.8345881	.008849558
114	12996	1481544	10.6770733	4.8488076	.008771930
115	13225	1520875	10.7238053	4.8629442	.008695652
116	13456	1560896	10.7703296	4.8769990	.008620690
117	13689	1601613	10.8166538	4.8909732	.008547009
118	13924	1643032	10.8627305	4.9048681	.008474576
119	14161	1685159	10.9087121	4.9186847	.008403361
120	14400	1728000	10.9544512	4.9324242	.008333333
121	14641	1771561	11.0000000	4.9460874	.008264463
122	14884	1815848	11.0453610	4.9596757	.008196721
123	15129	1860867	11.0905365	4.9731898	.008130081
124	15376	1906624	11.1355287	4.9866310	.008064516

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
125	15625	1953125	11.1803399	5.0000000	.008000000
126	15876	2000376	11.2249722	5.0132979	.007936508
127	16129	2048383	11.2694277	5.0265257	.007874016
128	16384	2097152	11.3137085	5.0396842	.007812500
129	16641	2146689	11.3578167	5.0527743	.007751938
130	16900	2197000	11.4017543	5.0657970	.007692308
131	17161	2248091	11.4455231	5.0787531	.007633588
132	17424	2299968	11.4891253	5.0916434	.007575758
133	17689	2352637	11.5325626	5.1044687	.007518797
134	17956	2406104	11.5758369	5.1172299	.007462687
135	18225	2460375	11.6189500	5.1299278	.007407407
136	18496	2515456	11.6619038	5.1425632	.007352941
137	18769	2571353	11.7046999	5.1551367	.007299270
138	19044	2628072	11.7473401	5.1676493	.007246377
139	19321	2685619	11.7898261	5.1801015	.007194245
140	19600	2744000	11.8321596	5.1924941	.007142857
141	19881	2803221	11.8743421	5.2048279	.007092199
142	20164	2863288	11.9163753	5.2171034	.007042254
143	20449	2924207	11.9582607	5.2293215	.006993007
144	20736	2985984	12.0000000	5.2414828	.006944444
145	21025	3048625	12.0415946	5.2535879	.006896552
146	21316	3112136	12.0830460	5.2656374	.006849315
147	21609	3176523	12.1243557	5.2776321	.006802721
148	21904	3241792	12.1655251	5.2895725	.006756757
149	22201	3307949	12.2065556	5.3014592	.006711409
150	22500	3375000	12.2474487	5.3132928	.006666667
151	22801	3442951	12.2882057	5.3250740	.006622517
152	23104	3511808	12.3288280	5.3368033	.006578947
153	23409	3581577	12.3693169	5.3484812	.006535948
154	23716	3652264	12.4096736	5.3601084	.006493506
155	24025	3723875	12.4498996	5.3716854	.006451613
156	24336	3796416	12.4899960	5.3832126	.006410256
157	24649	3869893	12.5299641	5.3946907	.006369427
158	24964	3944312	12.5698051	5.4061202	.006329114
159	25281	4019679	12.6095202	5.4175015	.006289308
160	25600	4096000	12.6491106	5.4288352	.006250000
161	25921	4173281	12.6885775	5.4401218	.006211180
162	26244	4251528	12.7279221	5.4513618	.006172840
163	26569	4330747	12.7671453	5.4625556	.006134969
164	26896	4410944	12.8062485	5.4737037	.006097561
165	27225	4492125	12.8452326	5.4848066	.006060606
166	27556	4574296	12.8840987	5.4958647	.006024096
167	27889	4657463	12.9228480	5.5068784	.005988024
168	28224	4741632	12.9614814	5.5178484	.005952381
169	28561	4826809	13.0000000	5.5287748	.005917160
170	28900	4913000	13.0384048	5.5396583	.005882353
171	29241	5000211	13.0766968	5.5504991	.005847953
172	29584	5088448	13.1148770	5.5612978	.005813953
173	29929	5177717	13.1529464	5.5720546	.005780347
174	30276	5268024	13.1909060	5.5827702	.005747126
175	30625	5359375	13.2287566	5.5934447	.005714286
176	30976	5451776	13.2664992	5.6040787	.005681818
177	31329	5545233	13.3041347	5.6146724	.005649718
178	31684	5639752	13.3416641	5.6252263	.005617978
179	32041	5735339	13.3790882	5.6357408	.005586592
180	32400	5832000	13.4164079	5.6462162	.005555556
181	32761	5929741	13.4536240	5.6566528	.005524862
182	33124	6028568	13.4907376	5.6670511	.005494505
183	33489	6128487	13.5277493	5.6774114	.005464481
184	33856	6229504	13.5646600	5.6877340	.005434783
185	34225	6331625	13.6014705	5.6980192	.005405405
186	34596	6434856	13.6381817	5.7082675	.005376344

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
187	34969	6539203	13.6747943	5.7184791	.005347594
188	35344	6644672	13.7113092	5.7286543	.005319149
189	35721	6751269	13.7477271	5.7387936	.005291005
190	36100	6859000	13.7840488	5.7488971	.005263158
191	36481	6967871	13.8202750	5.7589652	.005235602
192	36864	7077888	13.8564065	5.7689982	.005208333
193	37249	7189057	13.8924440	5.7789966	.005181347
194	37636	7301384	13.9283883	5.7889604	.005154639
195	38025	7414875	13.9642400	5.7988900	.005128205
196	38416	7529536	14.0000000	5.8087857	.005102041
197	38809	7645373	14.0356688	5.8186479	.005076142
198	39204	7762392	14.0712473	5.8284767	.005050505
199	39601	7880599	14.1067360	5.8382725	.005025126
200	40000	8000000	14.1421356	5.8480355	.005000000
201	40401	8120601	14.1774469	5.8577660	.004975124
202	40804	8242408	14.2126704	5.8674643	.004950495
203	41209	8365427	14.2478068	5.8771307	.004926108
204	41616	8489664	14.2828569	5.8867653	.004901961
205	42025	8615125	14.3178211	5.8963685	.004878049
206	42436	8741816	14.3527001	5.9059406	.004854369
207	42849	8869743	14.3874946	5.9154817	.004830918
208	43264	8998912	14.4222051	5.9249921	.004807692
209	43681	9129329	14.4568323	5.9344721	.004784689
210	44100	9261000	14.4913767	5.9439220	.004761905
211	44521	9393931	14.5258390	5.9533418	.004739336
212	44944	9528128	14.5602198	5.9627320	.004716981
213	45369	9663597	14.5945195	5.9720926	.004694836
214	45796	9800344	14.6287388	5.9814240	.004672897
215	46225	9938375	14.6628783	5.9907264	.004651163
216	46656	10077696	14.6969385	6.0000000	.004629630
217	47089	10218313	14.7309199	6.0092450	.004608295
218	47524	10360232	14.7648231	6.0184617	.004587156
219	47961	10503459	14.7986486	6.0276502	.004566210
220	48400	10648000	14.8323970	6.0368107	.004545455
221	48841	10793861	14.8660687	6.0459435	.004524887
222	49284	10941048	14.8996644	6.0550489	.004504505
223	49729	11089567	14.9331845	6.0641270	.004484305
224	50176	11239424	14.9666295	6.0731779	.004464286
225	50625	11390625	15.0000000	6.0822020	.004444444
226	51076	11543176	15.0332964	6.0911994	.004424779
227	51529	11697083	15.0665192	6.1001702	.004405286
228	51984	11852352	15.0996689	6.1091147	.004385965
229	52441	12008989	15.1327460	6.1180332	.004366812
230	52900	12167000	15.1657509	6.1269257	.004347826
231	53361	12326391	15.1986842	6.1357924	.004329004
232	53824	12487168	15.2315462	6.1446337	.004310345
233	54289	12649337	15.2643375	6.1534495	.004291845
234	54756	12812904	15.2970585	6.1622401	.004273504
235	55225	12977875	15.3297097	6.1710058	.004255319
236	55696	13144256	15.3622915	6.1797466	.004237288
237	56169	13312053	15.3948043	6.1884628	.004219409
238	56644	13481272	15.4272486	6.1971544	.004201681
239	57121	13651919	15.4596248	6.2058218	.004184100
240	57600	13824000	15.4919334	6.2144650	.004166667
241	58081	13997521	15.5241747	6.2230843	.004149378
242	58564	14172488	15.5563492	6.2316797	.004132231
243	59049	14348907	15.5884573	6.2402515	.004115226
244	59536	14526784	15.6204994	6.2487998	.004098361
245	60025	14706125	15.6524758	6.2573248	.004081633
246	60516	14886936	15.6843871	6.2658266	.004065041
247	61009	15069223	15.7162336	6.2743054	.004048583
248	61504	15252992	15.7480157	6.2827613	.004032263

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
249	62001	15438249	15.7797338	6.2911946	.004016064
250	62500	15625000	15.8113883	6.2996053	.004000000
251	63001	15813251	15.8429795	6.3079935	.003984064
252	63504	16003008	15.8745079	6.3163596	.003968254
253	64009	16194277	15.9059737	6.3247035	.003952569
254	64516	16387064	15.9373775	6.3330256	.003937008
255	65025	16581375	15.9687194	6.3413257	.003921569
256	65536	16777216	16.0000000	6.3496042	.003906250
257	66049	16974593	16.0312195	6.3578611	.003891051
258	66564	17173512	16.0623784	6.3660968	.003875969
259	67081	17373979	16.0934769	6.3743111	.003861004
260	67600	17576000	16.1245155	6.3825043	.003846154
261	68121	17779581	16.1554944	6.3906765	.003831418
262	68644	17984728	16.1864141	6.3988279	.003816794
263	69169	18191447	16.2172747	6.4069585	.003802281
264	69696	18399744	16.2480768	6.4150687	.003787879
265	70225	18609625	16.2788206	6.4231583	.003773585
266	70756	18821096	16.3095064	6.4312276	.003759398
267	71289	19034163	16.3401346	6.4392767	.003745318
268	71824	19248832	16.3707055	6.4473057	.003731343
269	72361	19465109	16.4012195	6.4553148	.003717472
270	72900	19683000	16.4316767	6.4633041	.003703704
271	73441	19902511	16.4620776	6.4712736	.003690037
272	73984	20123648	16.4924225	6.4792236	.003676471
273	74529	20346417	16.5227116	6.4871541	.003663004
274	75076	20570824	16.5529454	6.4950653	.003649635
275	75625	20796875	16.5831240	6.5029572	.003636364
276	76176	21024576	16.6132477	6.5108300	.003623188
277	76729	21253933	16.6433170	6.5186839	.003610108
278	77284	21484952	16.6733320	6.5265189	.003597122
279	77841	21717639	16.7032931	6.5343351	.003584229
280	78400	21952000	16.7332005	6.5421326	.003571429
281	78961	22188041	16.7630546	6.5499116	.003558719
282	79524	22425768	16.7928556	6.5576722	.003546099
283	80089	22665187	16.8226038	6.5654144	.003533569
284	80656	22906304	16.8522995	6.5731385	.003521127
285	81225	23149125	16.8819430	6.5808443	.003508772
286	81796	23393656	16.9115345	6.5885323	.003496503
287	82369	23639903	16.9410743	6.5962023	.003484321
288	82944	23887872	16.9705627	6.6038545	.003472222
289	83521	24137569	17.0000000	6.6114890	.003460208
290	84100	24389000	17.0293864	6.6191060	.003448276
291	84681	24642171	17.0587221	6.6267054	.003436426
292	85264	24897088	17.0880075	6.6342874	.003424658
293	85849	25153757	17.1172428	6.6418522	.003412969
294	86436	25412184	17.1464282	6.6493998	.003401361
295	87025	25672375	17.1755640	6.6569302	.003389831
296	87616	25934336	17.2046505	6.6644437	.003378378
297	88209	26198073	17.2336879	6.6719403	.003366903
298	88804	26463592	17.2626765	6.6794200	.003355505
299	89401	26730899	17.2916165	6.6868831	.003344482
300	90000	27000000	17.3205081	6.6943295	.003333333
301	90601	27270901	17.3493516	6.7017593	.003322259
302	91204	27543608	17.3781472	6.7091729	.003311258
303	91809	27818127	17.4068952	6.7165700	.003300330
304	92416	28094464	17.4355958	6.7239508	.003289474
305	93025	28372625	17.4642492	6.7313155	.003278689
306	93636	28652616	17.4928557	6.7386641	.003267974
307	94249	28934443	17.5214155	6.7459967	.003257329
308	94864	29218112	17.5499288	6.7533134	.003246753
309	95481	29503629	17.5783958	6.7606143	.003236246
310	96100	29791000	17.6068169	6.7678995	.003225806

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
311	96721	30080231	17.6351921	6.7751690	.003215434
312	97344	30371328	17.6635217	6.7824229	.003205128
313	97969	30664297	17.6918060	6.7896613	.003194888
314	98596	30959144	17.7200451	6.7968844	.003184713
315	99225	31255875	17.7482393	6.8040921	.003174603
316	99856	31554496	17.7763888	6.8112847	.003164557
317	100489	31855013	17.8044938	6.8184620	.003154574
318	101124	32157432	17.8325545	6.8256242	.003144654
319	101761	32461759	17.8605711	6.8327714	.003134796
320	102400	32768000	17.8885438	6.8399037	.003125000
321	103041	33076161	17.9164729	6.8470213	.003115265
322	103684	33386248	17.9443584	6.8541240	.003105590
323	104329	33698267	17.9722008	6.8612120	.003095975
324	104976	34012224	18.0000000	6.8682855	.003086420
325	105625	34328125	18.0277564	6.8753443	.003076923
326	106276	34645976	18.0554701	6.8823888	.003067485
327	106929	34965783	18.0831413	6.8894188	.003058104
328	107584	35287552	18.1107703	6.8964345	.003048780
329	108241	35611289	18.1383571	6.9034359	.003039514
330	108900	35937000	18.1659021	6.9104232	.003030303
331	109561	36264691	18.1934054	6.9173964	.003021148
332	110224	36594368	18.2208672	6.9243556	.003012048
333	110889	36926037	18.2482876	6.9313008	.003003003
334	111556	37259704	18.2756669	6.9382321	.002994012
335	112225	37595375	18.3030052	6.9451496	.002985075
336	112896	37933056	18.3303028	6.9520533	.002976190
337	113569	38272753	18.3575598	6.9589434	.002967359
338	114244	38614472	18.3847763	6.9658198	.002958580
339	114921	38958219	18.4119526	6.9726826	.002949853
340	115600	39304000	18.4390889	6.9795321	.002941176
341	116281	39651821	18.4661853	6.9863681	.002932551
342	116964	40001688	18.4932420	6.9931906	.002923977
343	117649	40353607	18.5202592	7.0000000	.002915452
344	118336	40707584	18.5472370	7.0067962	.002906977
345	119025	41063625	18.5741756	7.0135791	.002898551
346	119716	41421736	18.6010752	7.0203490	.002890173
347	120409	41781923	18.6279360	7.0271058	.002881844
348	121104	42144192	18.6547581	7.0338497	.002873563
349	121801	42508549	18.6815417	7.0405806	.002865330
350	122500	42875000	18.7082869	7.0472987	.002857143
351	123201	43243551	18.7349940	7.0540041	.002849003
352	123904	43614208	18.7616630	7.0606967	.002840909
353	124609	43986977	18.7882942	7.0673767	.002832861
354	125316	44361864	18.8148877	7.0740440	.002824859
355	126025	44738875	18.8414437	7.0806988	.002816901
356	126736	45118016	18.8679623	7.0873411	.002808989
357	127449	45499293	18.8944436	7.0939709	.002801120
358	128164	45882712	18.9208879	7.1005885	.002793296
359	128881	46268279	18.9472953	7.1071937	.002785515
360	129600	46656000	18.9736660	7.1137866	.002777778
361	130321	47045881	19.0000000	7.1203674	.002770083
362	131044	47437928	19.0262976	7.1269360	.002762431
363	131769	47832147	19.0525589	7.1334925	.002754821
364	132496	48228544	19.0787840	7.1400370	.002747253
365	133225	48627125	19.1049732	7.1465695	.002739726
366	133956	49027896	19.1311265	7.1530901	.002732240
367	134689	49430863	19.1572441	7.1595988	.002724796
368	135424	49836032	19.1833261	7.1660957	.002717391
369	136161	50243409	19.2093727	7.1725809	.002710027
370	136900	50653000	19.2353841	7.1790544	.002702703
371	137641	51064811	19.2613603	7.1855162	.002695418
372	138384	51478848	19.2873015	7.1919663	.002688172

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciproals.
373	139129	51895117	19.3132079	7.1984050	.002680965
374	139876	52313624	19.3390796	7.2048322	.002673797
375	140625	52734375	19.3649167	7.2112479	.002666667
376	141376	53157376	19.3907194	7.2176522	.002659574
377	142129	53582633	19.4164878	7.2240450	.002652520
378	142884	54010152	19.4422221	7.2304268	.002645503
379	143641	54439939	19.4679223	7.2368792	.002638522
380	144400	54872000	19.4935887	7.2431565	.002631579
381	145161	55306341	19.5192213	7.2495045	.002624672
382	145924	55742968	19.5448203	7.2558415	.002617801
383	146689	56181887	19.5703858	7.2621675	.002610966
384	147456	56623104	19.5959179	7.2684824	.002604167
385	148225	57066625	19.6214169	7.2747864	.002597403
386	148996	57512436	19.6468827	7.2810794	.002590674
387	149769	57960603	19.6723156	7.2873617	.002583979
388	150544	58411072	19.6977156	7.2936330	.002577320
389	151321	58863869	19.7230829	7.2998936	.002570694
390	152100	59319000	19.7484177	7.3061436	.002564103
391	152881	59776471	19.7737199	7.3123828	.002557545
392	153664	60236288	19.7989899	7.3186114	.002551020
393	154449	60698457	19.8242276	7.3248295	.002544529
394	155236	61162984	19.8494332	7.3310369	.002538071
395	156025	61629875	19.8746069	7.3372339	.002531646
396	156816	62099136	19.8997487	7.3434205	.002525253
397	157609	62570773	19.9248588	7.3495966	.002518892
398	158404	63044792	19.9499373	7.3557624	.002512563
399	159201	63521199	19.9749844	7.3619178	.002506266
400	160000	64000000	20.0000000	7.3680630	.002500000
401	160801	64481201	20.0249844	7.3741979	.002493766
402	161604	64964808	20.0499377	7.3803227	.002487522
403	162409	65450827	20.0748599	7.3864373	.002481390
404	163216	65939264	20.0997512	7.3925418	.002475248
405	164025	66430125	20.1246118	7.3986363	.002469136
406	164836	66923416	20.1494417	7.4047206	.002463054
407	165649	67419143	20.1742410	7.4107950	.002457002
408	166464	67917312	20.1990099	7.4168595	.002450980
409	167281	68417929	20.2237484	7.4229142	.002444988
410	168100	68921000	20.2484567	7.4289589	.002439024
411	168921	69426531	20.2731349	7.4349938	.002433090
412	169744	69934528	20.2977831	7.4410189	.002427184
413	170569	70444997	20.3224014	7.4470342	.002421308
414	171396	70957944	20.3469899	7.4530399	.002415459
415	172225	71473375	20.3715488	7.4590359	.002409639
416	173056	71991296	20.3960781	7.4650223	.002403846
417	173889	72511713	20.4205779	7.4709991	.002398082
418	174724	73034632	20.4450483	7.4769664	.002392344
419	175561	73560059	20.4694895	7.4829242	.002386635
420	176400	74088000	20.4939015	7.4888724	.002380952
421	177241	74618461	20.5182845	7.4948113	.002375297
422	178084	75151448	20.5426386	7.5007406	.002369668
423	178929	75686967	20.5669638	7.5066607	.002364066
424	179776	76225024	20.5912603	7.5125715	.002358491
425	180625	76765625	20.6155281	7.5184730	.002352941
426	181476	77308776	20.6397674	7.5243652	.002347418
427	182329	77854483	20.6639783	7.5302482	.002341920
428	183184	78402752	20.6881609	7.5361221	.002336449
429	184041	78953589	20.7123152	7.5419867	.002331002
430	184900	79507000	20.7364414	7.5478423	.002325581
431	185761	80062991	20.7605395	7.5536888	.002320186
432	186624	80621568	20.7846097	7.5595263	.002314815
433	187489	81182737	20.8086520	7.5653548	.002309469
434	188356	81746504	20.8326667	7.5711743	.002304147

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
435	189225	82312875	20.8566536	7.5769849	.002298851
436	190096	82881856	20.8806130	7.5827865	.002293578
437	190969	83453453	20.9045450	7.5885793	.002288330
438	191844	84027672	20.9284495	7.5943633	.002283105
439	192721	84604519	20.9523268	7.6001385	.002277904
440	193600	85184000	20.9761770	7.6059049	.002272727
441	194481	85766121	21.0000000	7.6116626	.002267574
442	195364	86350888	21.0237960	7.6174116	.002262443
443	196249	86938307	21.0475652	7.6231519	.002257336
444	197136	87528384	21.0713075	7.6288837	.002252252
445	198025	88121125	21.0950231	7.6346067	.002247191
446	198916	88716536	21.1187121	7.6403213	.002242152
447	199809	89314623	21.1423745	7.6460272	.002237136
448	200704	89915392	21.1660105	7.6517247	.002232143
449	201601	90518849	21.1896201	7.6574138	.002227171
450	202500	91125000	21.2132034	7.6630943	.002222222
451	203401	91733851	21.2367606	7.6687665	.002217295
452	204304	92345408	21.2602916	7.6744303	.002212389
453	205209	92959677	21.2837967	7.6800857	.002207506
454	206116	93576664	21.3072758	7.6857328	.002202643
455	207025	94196375	21.3307290	7.6913717	.002197802
456	207936	94818816	21.3541565	7.6970023	.002192982
457	208849	95443993	21.3775583	7.7026246	.002188184
458	209764	96071912	21.4009346	7.7082388	.002183406
459	210681	96702579	21.4242853	7.7138448	.002178649
460	211600	97336000	21.4476106	7.7194426	.002173913
461	212521	97972181	21.4709106	7.7250325	.002169197
462	213444	98611128	21.4941853	7.7306141	.002164502
463	214369	99252847	21.5174348	7.7361877	.002159827
464	215296	99897344	21.5406592	7.7417532	.002155172
465	216225	100546625	21.5638587	7.7473109	.002150538
466	217156	101194696	21.5870331	7.7528606	.002145923
467	218089	101847563	21.6101828	7.7584023	.002141328
468	219024	102503232	21.6333077	7.7639361	.002136752
469	219961	103161709	21.6564078	7.7694620	.002132196
470	220900	103823000	21.6794834	7.7749801	.002127660
471	221841	104487111	21.7025344	7.7804904	.002123142
472	222784	105154048	21.7255610	7.7859928	.002118644
473	223729	105823817	21.7485632	7.7914875	.002114165
474	224676	106496424	21.7715411	7.7969745	.002109705
475	225625	107171875	21.7944947	7.8024538	.002105263
476	226576	107850176	21.8174242	7.8079254	.002100840
477	227529	108531333	21.8403297	7.8133892	.002096436
478	228484	109215352	21.8632111	7.8188456	.002092050
479	229441	109902239	21.8860686	7.8242942	.002087683
480	230400	110592000	21.9089023	7.8297353	.002083333
481	231361	111284641	21.9317122	7.8351688	.002079002
482	232324	111980168	21.9544984	7.8405949	.002074689
483	233289	112678587	21.9772610	7.8460134	.002070393
484	234256	113379904	22.0000000	7.8514244	.002066116
485	235225	114084125	22.0227155	7.8568281	.002061856
486	236196	114791256	22.0454077	7.8622242	.002057613
487	237169	115501303	22.0680765	7.8676130	.002053388
488	238144	116214272	22.0907220	7.8729944	.002049180
489	239121	116930169	22.1133444	7.8783684	.002044990
490	240100	117649000	22.1359436	7.8837352	.002040816
491	241081	118370771	22.1585198	7.8890946	.002036660
492	242064	119095488	22.1810730	7.8944468	.002032520
493	243049	119823157	22.2036033	7.8997917	.002028398
494	244036	120553784	22.2261108	7.9051294	.002024291
495	245025	121287375	22.2485955	7.9104599	.002020202
496	246016	122023936	22.2710575	7.9157832	.002016129

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
497	247009	122763473	22.2934968	7.9210994	.002012072
498	248004	123505992	22.3159136	7.9264085	.002008032
499	249001	124251499	22.3383079	7.9317104	.002004008
500	250000	125000000	22.3606798	7.9370053	.002000000
501	251001	125751501	22.3830293	7.9422931	.001996008
502	252004	126506008	22.4053565	7.9475739	.001992032
503	253009	127263527	22.4276615	7.9528477	.001988072
504	254016	128024064	22.4499443	7.9581144	.001984127
505	255025	128787625	22.4722051	7.9633743	.001980198
506	256036	129554216	22.4944438	7.9686271	.001976285
507	257049	130323843	22.5166605	7.9738731	.001972387
508	258064	131096512	22.5388553	7.9791122	.001968504
509	259081	131872229	22.5610283	7.9843444	.001964637
510	260100	132651000	22.5831796	7.9895697	.001960784
511	261121	133432831	22.6053091	7.9947883	.001956947
512	262144	134217728	22.6274170	8.0000000	.001953125
513	263169	135005697	22.6495033	8.0052049	.001949318
514	264196	135796744	22.6715681	8.0104032	.001945525
515	265225	136590875	22.6936114	8.0155946	.001941748
516	266256	137388096	22.7156334	8.0207794	.001937984
517	267289	138188413	22.7376340	8.0259574	.001934236
518	268324	138991832	22.7596134	8.0311287	.001930502
519	269361	139798359	22.7815715	8.0362935	.001926782
520	270400	140608000	22.8035085	8.0414515	.001923077
521	271441	141420761	22.8254244	8.0466030	.001919386
522	272484	142236648	22.8473193	8.0517479	.001915709
523	273529	143055667	22.8691933	8.0568862	.001912046
524	274576	143877824	22.8910463	8.0620180	.001908397
525	275625	144703125	22.9128785	8.0671432	.001904762
526	276676	145531576	22.9346899	8.0722620	.001901141
527	277729	146363183	22.9564806	8.0773743	.001897533
528	278784	147197952	22.9782506	8.0824800	.001893939
529	279841	148035889	23.0000000	8.0875794	.001890359
530	280900	148877000	23.0217289	8.0926723	.001886792
531	281961	149721291	23.0434372	8.0977789	.001883239
532	283024	150568768	23.0651252	8.1028930	.001879699
533	284089	151419437	23.0867928	8.1079128	.001876173
534	285156	152273304	23.1084400	8.1129803	.001872659
535	286225	153130375	23.1300670	8.1180414	.001869159
536	287296	153990656	23.1516738	8.1230962	.001865672
537	288369	154854153	23.1732605	8.1281447	.001862197
538	289444	155720872	23.1948270	8.1331870	.001858736
539	290521	156590819	23.2163735	8.1382230	.001855288
540	291600	157464000	23.2379001	8.1432529	.001851852
541	292681	158340421	23.2594067	8.1482765	.001848429
542	293764	159220038	23.2808935	8.1532939	.001845018
543	294849	160103007	23.3023604	8.1583051	.001841621
544	295936	160989184	23.3238076	8.1633102	.001838235
545	297025	161878625	23.3452351	8.1683092	.001834862
546	298116	162771336	23.3666429	8.1733020	.001831502
547	299209	163667323	23.3880311	8.1782888	.001828154
548	300304	164566592	23.4093998	8.1832695	.001824818
549	301401	165469149	23.4307490	8.1882441	.001821494
550	302500	166375000	23.4520788	8.1932127	.001818182
551	303601	167284151	23.4733892	8.1981752	.001814882
552	304704	168196608	23.4946802	8.2031319	.001811594
553	305809	169112377	23.5159520	8.2080825	.001808318
554	306916	170031464	23.5372046	8.2130271	.001805054
555	308025	170953875	23.5584380	8.2179657	.001801802
556	309136	171879616	23.5796522	8.2228985	.001798561
557	310249	172808693	23.6008474	8.2278254	.001795332
558	311364	173741112	23.6220236	8.2327463	.001792115

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
559	312481	174676879	23.0431808	8.2376614	.001788909
560	313600	175616000	23.0643191	8.2425706	.001785714
561	314721	176558481	23.0854386	8.2474740	.001782531
562	315844	177504328	23.1065392	8.2523715	.001779359
563	316969	178453547	23.1276210	8.2572633	.001776199
564	318096	179406144	23.1486842	8.2621492	.001773050
565	319225	180362125	23.1697286	8.2670294	.001769912
566	320356	181321496	23.1907545	8.2719039	.001766784
567	321489	182284263	23.2117618	8.2767726	.001763668
568	322624	183250432	23.2327506	8.2816355	.001760563
569	323761	184220009	23.2537209	8.2864928	.001757469
570	324900	185193000	23.2746728	8.2913444	.001754386
571	326041	186169411	23.2956063	8.2961903	.001751313
572	327184	187149248	23.3165215	8.3010304	.001748252
573	328329	188132517	23.3374184	8.3058651	.001745201
574	329476	189119224	23.3582971	8.3106941	.001742160
575	330625	190109375	23.3791576	8.3155175	.001739130
576	331776	191102976	24.0000000	8.3203353	.001736111
577	332929	192100033	24.0208213	8.3251475	.001733102
578	334084	193100552	24.0416306	8.3299542	.001730104
579	335241	194104529	24.0624188	8.3347553	.001727116
580	336400	195112000	24.0831891	8.3395509	.001724138
581	337561	196122941	24.1039416	8.3443410	.001721170
582	338724	197137368	24.1246762	8.3491256	.001718213
583	339889	198155287	24.1453929	8.3539047	.001715266
584	341056	199176704	24.1660919	8.3586784	.001712329
585	342225	200201625	24.1867732	8.3634466	.001709402
586	343396	201229056	24.2074369	8.3682095	.001706485
587	344569	202260003	24.2280829	8.3729668	.001703578
588	345744	203294722	24.2487113	8.3777188	.001700680
589	346921	204333649	24.2693222	8.3824653	.001697793
590	348100	205376000	24.2899156	8.3872065	.001694915
591	349281	2064225071	24.3104916	8.3919423	.001692047
592	350464	207473688	24.3310501	8.3966729	.001689189
593	351649	208527857	24.3515913	8.4013981	.001686341
594	352836	209584584	24.3721152	8.4061180	.001683502
595	354025	210644875	24.3926218	8.4108326	.001680672
596	355216	211708736	24.4131112	8.4155419	.001677852
597	356409	212776173	24.4335834	8.4202460	.001675042
598	357604	213847192	24.4540385	8.4249448	.001672241
599	358801	214921799	24.4744765	8.4296383	.001669449
600	360000	216000000	24.4948974	8.4343267	.001666667
601	361201	217081801	24.5153013	8.4390098	.001663894
602	362404	218167208	24.5356883	8.4436877	.001661130
603	363609	219256227	24.5560583	8.4483605	.001658375
604	364816	220348864	24.5764115	8.4530281	.001655629
605	366025	221445125	24.5967478	8.4576906	.001652893
606	367236	222545016	24.6170673	8.4623479	.001650165
607	368449	223648543	24.6373700	8.4670001	.001647446
608	369664	224755712	24.6576560	8.4716471	.001644737
609	370881	225866529	24.6779254	8.4762892	.001642036
610	372100	226981000	24.6981781	8.4809261	.001639344
611	373321	228099131	24.7184142	8.4855579	.001636661
612	374544	229220928	24.7386338	8.4901848	.001633987
613	375769	230346397	24.7588368	8.4948065	.001631321
614	376996	231475544	24.7790234	8.4994233	.001628664
615	378225	232608375	24.7991933	8.5040350	.001626016
616	379456	233744896	24.8193473	8.5086417	.001623377
617	380689	234885113	24.8394847	8.5132435	.001620746
618	381924	236029032	24.8596058	8.5178403	.001618123
619	383161	237176659	24.8797106	8.5224321	.001615509
620	384400	238328000	24.8997992	8.5270189	.001612903

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
621	385641	239483061	24.9198716	8.5316009	.001610306
622	386884	240641848	24.9399278	8.5361780	.001607717
623	388129	241804867	24.9599679	8.5407501	.001605136
624	389376	242970624	24.9799920	8.5453173	.001602564
625	390625	244140625	25.0000000	8.5498797	.001600000
626	391876	245314376	25.0199920	8.5544372	.001597444
627	393129	246491883	25.0399681	8.5589899	.001594896
628	394384	247673152	25.0599282	8.5635377	.001592357
629	395641	248858189	25.0798724	8.5680807	.001589825
630	396900	250047000	25.0998008	8.5726189	.001587302
631	398161	251239591	25.1197134	8.5771523	.001584786
632	399424	252435968	25.1396102	8.5816809	.001582278
633	400689	253636137	25.1594913	8.5862047	.001579779
634	401956	254840104	25.1793566	8.5907238	.001577287
635	403225	256047875	25.1992063	8.5952380	.001574803
636	404496	257259456	25.2190404	8.5997476	.001572327
637	405769	258474853	25.2388589	8.6042525	.001569859
638	407044	259694072	25.2586619	8.6087526	.001567398
639	408321	260917119	25.2784493	8.6132480	.001564945
640	409600	262144000	25.2982213	8.6177388	.001562500
641	410881	263374721	25.3179778	8.6222248	.001560062
642	412164	264609288	25.3377189	8.6267063	.001557632
643	413449	265847707	25.3574447	8.6311830	.001555210
644	414736	267089984	25.3771551	8.6356551	.001552795
645	416025	268336125	25.3968502	8.6401226	.001550388
646	417316	269586136	25.4165301	8.6445855	.001547988
647	418609	270840033	25.4361947	8.6490437	.001545595
648	419904	272097792	25.4558441	8.6534974	.001543210
649	421201	273359449	25.4754784	8.6579465	.001540832
650	422500	274625000	25.4950976	8.6623911	.001538462
651	423801	275894451	25.5147016	8.6668310	.001536098
652	425104	277167808	25.5342907	8.6712665	.001533742
653	426409	278445077	25.5538647	8.6756974	.001531394
654	427716	279726264	25.5734237	8.6801237	.001529052
655	429025	281011375	25.5929678	8.6845456	.001526718
656	430336	282300416	25.6124969	8.6889630	.001524390
657	431649	283593393	25.6320112	8.6933759	.001522070
658	432964	284890312	25.6515107	8.6977843	.001519757
659	434281	286191179	25.6709963	8.7021882	.001517451
660	435600	287496000	25.6904652	8.7065877	.001515152
661	436921	288804781	25.7099203	8.7109827	.001512859
662	438244	290117528	25.7293607	8.7153734	.001510574
663	439569	291434247	25.7487864	8.7197596	.001508296
664	440896	292754944	25.7681975	8.7241414	.001506024
665	442225	294079625	25.7875939	8.7285187	.001503759
666	443556	295408296	25.8069758	8.7328918	.001501502
667	444889	296740963	25.8263431	8.7372604	.001499250
668	446224	298077632	25.8456960	8.7416246	.001497006
669	447561	299418309	25.8650343	8.7459846	.001494768
670	448900	300763000	25.8843582	8.7503401	.001492537
671	450241	302111711	25.9036677	8.7546913	.001490313
672	451584	303464448	25.9229628	8.7590383	.001488095
673	452929	304821217	25.9422435	8.7633809	.001485884
674	454276	306182024	25.9615100	8.7677192	.001483680
675	455625	307546875	25.9807621	8.7720532	.001481481
676	456976	308915776	26.0000000	8.7763830	.001479290
677	458329	310288733	26.0192237	8.7807084	.001477105
678	459684	311665752	26.0384331	8.7850296	.001474926
679	461041	313046839	26.0576284	8.7893466	.001472754
680	462400	314432000	26.0768096	8.7936593	.001470588
681	463761	315821241	26.0959767	8.7979679	.001468429
682	465124	317214568	26.1151297	8.8022721	.001466276

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
683	466489	318611987	26.1342687	8.8065722	.001464129
684	467856	320013504	26.1533937	8.8108681	.001461988
685	469225	321419125	26.1725047	8.8151598	.001459854
686	470596	322828856	26.1916017	8.8194474	.001457726
687	471969	324242703	26.2106848	8.8237307	.001455604
688	473344	325660672	26.2297541	8.8280099	.001453488
689	474721	327082769	26.2488095	8.8322850	.001451379
690	476100	328509000	26.2678511	8.8365559	.001449275
691	477481	329939371	26.2868789	8.8408227	.001447178
692	478864	331373888	26.3058929	8.8450854	.001445087
693	480249	332812557	26.3248932	8.8493440	.001443001
694	481636	334255384	26.3438797	8.8535985	.001440922
695	483025	335702375	26.3628527	8.8578489	.001438849
696	484416	337153536	26.3818119	8.8620952	.001436782
697	485809	338608873	26.4007576	8.8663375	.001434720
698	487204	340068392	26.4196896	8.8705757	.001432665
699	488601	341532099	26.4386081	8.8748099	.001430615
700	490000	343000000	26.4575131	8.8790400	.001428571
701	491401	344472101	26.4764046	8.8832661	.001426534
702	492804	345948408	26.4952826	8.8874882	.001424501
703	494209	347428927	26.5141472	8.8917063	.001422475
704	495616	348913664	26.5329983	8.8959204	.001420455
705	497025	350402625	26.5518361	8.9001304	.001418440
706	498436	351895816	26.5706605	8.9043366	.001416431
707	499849	353393243	26.5894716	8.9085387	.001414427
708	501264	354894912	26.6082694	8.9127369	.001412429
709	502681	356400829	26.6270539	8.9169311	.001410437
710	504100	357911000	26.6458252	8.9211214	.001408451
711	505521	359425431	26.6645833	8.9253078	.001406470
712	506944	360944128	26.6833281	8.9294902	.001404494
713	508369	362467097	26.7020598	8.9336687	.001402525
714	509796	363994344	26.7207784	8.9378433	.001400560
715	511225	365525875	26.7394839	8.9420140	.001398601
716	512656	367061696	26.7581763	8.9461809	.001396648
717	514089	368601813	26.7768557	8.9503438	.001394700
718	515524	370146232	26.7955220	8.9545029	.001392758
719	516961	371694959	26.8141754	8.9586581	.001390821
720	518400	373248000	26.8328157	8.9628095	.001388889
721	519841	374805361	26.8514432	8.9669570	.001386963
722	521284	376367048	26.8700577	8.9711007	.001385042
723	522729	377933067	26.8886593	8.9752406	.001383126
724	524176	379503424	26.9072481	8.9793766	.001381215
725	525625	381078125	26.9258240	8.9835089	.001379310
726	527076	382657176	26.9443872	8.9876373	.001377410
727	528529	384240583	26.9629375	8.9917620	.001375516
728	529984	385828352	26.9814751	8.9958829	.001373626
729	531441	387420489	27.0000000	9.0000000	.001371742
730	532900	389017000	27.0185122	9.0041134	.001369863
731	534361	390617891	27.0370117	9.0082229	.001367989
732	535824	392223168	27.0554985	9.0123288	.001366120
733	537289	393832837	27.0739727	9.0164309	.001364256
734	538756	395446904	27.0924344	9.0205293	.001362398
735	540225	397065375	27.1108834	9.0246239	.001360544
736	541696	398688256	27.1293199	9.0287149	.001358696
737	543169	400315553	27.1477439	9.0328021	.001356852
738	544644	401947272	27.1661554	9.0368857	.001355014
739	546121	403583419	27.1845544	9.0409655	.001353180
740	547600	405224000	27.2029410	9.0450417	.001351351
741	549081	406869021	27.2213152	9.0491142	.001349528
742	550564	408518488	27.2396769	9.0531831	.001347709
743	552049	410172407	27.2580263	9.0572482	.001345895
744	553536	411830784	27.2763634	9.0613098	.001344086

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
745	555025	413493625	27.2946881	9.0653677	.001342282
746	556516	415160936	27.3130006	9.0694220	.001340483
747	558009	416832723	27.3313007	9.0734726	.001338688
748	559504	418508992	27.3495887	9.0775197	.001336898
749	561001	420189749	27.3678644	9.0815631	.001335113
750	562500	421875000	27.3861279	9.0856030	.001333333
751	564001	423564751	27.4043792	9.0896392	.001331558
752	565504	425259008	27.4226184	9.0936719	.001329787
753	567009	426957777	27.4408455	9.0977010	.001328021
754	568516	428661064	27.4590604	9.1017265	.001326260
755	570025	430368875	27.4772632	9.1057485	.001324503
756	571536	432081216	27.4954542	9.1097669	.001322751
757	573049	433798093	27.5136330	9.1137818	.001321004
758	574564	435519512	27.5317998	9.1177931	.001319261
759	576081	437245479	27.5499546	9.1218010	.001317523
760	577600	438976000	27.5680975	9.1258053	.001315789
761	579121	440711081	27.5862284	9.1298061	.001314060
762	580644	442450728	27.6043475	9.1338034	.001312336
763	582169	444194947	27.6224546	9.1377971	.001310616
764	583696	445943744	27.6405499	9.1417874	.001308901
765	585225	447697125	27.6586334	9.1457742	.001307190
766	586756	449455096	27.6767050	9.1497576	.001305483
767	588289	451217663	27.6947648	9.1537375	.001303781
768	589824	452984832	27.7128129	9.1577139	.001302083
769	591361	454756609	27.7308492	9.1616869	.001300390
770	592900	456533000	27.7488739	9.1656565	.001298701
771	594441	458314011	27.7668868	9.1696225	.001297017
772	595984	460099648	27.7848880	9.1735852	.001295337
773	597529	461889917	27.8028775	9.1775445	.001293661
774	599076	463684824	27.8208555	9.1815003	.001291990
775	600625	465484375	27.8388218	9.1854527	.001290323
776	602176	467288576	27.8567766	9.1894018	.001288660
777	603729	469097433	27.8747197	9.1933474	.001287001
778	605284	470910952	27.8926514	9.1972897	.001285347
779	606841	472729139	27.9105715	9.2012286	.001283697
780	608400	474552000	27.9284801	9.2051641	.001282051
781	609961	476379541	27.9463772	9.2090962	.001280410
782	611524	478211768	27.9642629	9.2130250	.001278772
783	613089	480048687	27.9821372	9.2169505	.001277139
784	614656	481890304	28.0000000	9.2208726	.001275510
785	616225	483736625	28.0178515	9.2247914	.001273885
786	617796	485587656	28.0356915	9.2287068	.001272265
787	619369	487443403	28.0535203	9.2326189	.001270648
788	620944	489303872	28.0713377	9.2365277	.001269036
789	622521	491169069	28.0891438	9.2404333	.001267427
790	624100	493039000	28.1069386	9.2443355	.001265823
791	625681	494913671	28.1247222	9.2482344	.001264223
792	627264	496793088	28.1424946	9.2521300	.001262626
793	628849	498677257	28.1602557	9.2560224	.001261034
794	630436	500566184	28.1780056	9.2599114	.001259446
795	632025	502459875	28.1957444	9.2637973	.001257862
796	633616	504358336	28.2134720	9.2676798	.001256281
797	635209	506261573	28.2311884	9.2715592	.001254705
798	636804	508169592	28.2488938	9.2754352	.001253133
799	638401	510082399	28.2665881	9.2793081	.001251564
800	640000	512000000	28.2842712	9.2831777	.001250000
801	641601	513922401	28.3019434	9.2870440	.001248439
802	643204	515849608	28.3196045	9.2909072	.001246883
803	644809	517781627	28.3372546	9.2947671	.001245330
804	646416	519718464	28.3548938	9.2986239	.001243781
805	648025	521660125	28.3725219	9.3024775	.001242236
806	649636	523606616	28.3901391	9.3063278	.001240695

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
807	651249	525557943	28.4077454	9.3101750	.001239157
808	652864	527514112	28.4253408	9.3140190	.001237624
809	654481	5294725129	28.4429253	9.3178599	.001236094
810	656100	531441000	28.4604989	9.3216975	.001234568
811	657721	533411731	28.4780617	9.3255320	.001233046
812	659344	535387328	28.4956137	9.3293634	.001231527
813	660969	537367797	28.5131549	9.3331916	.001230012
814	662596	539353144	28.5306852	9.3370167	.001228501
815	664225	541343375	28.5482048	9.3408386	.001226994
816	665856	543338496	28.5657137	9.3446575	.001225490
817	667489	545338513	28.5832119	9.3484731	.001223990
818	669124	547343432	28.6006993	9.3522857	.001222494
819	670761	549353259	28.6181760	9.3560952	.001221001
820	672400	551368000	28.6356421	9.3599016	.001219512
821	674041	553387661	28.6530976	9.3637049	.001218027
822	675684	555412248	28.6705424	9.3675051	.001216545
823	677329	557441767	28.6879766	9.3713022	.001215067
824	678976	559476224	28.7054002	9.3750963	.001213592
825	680625	561515625	28.7228132	9.3788873	.001212121
826	682276	563559976	28.7402157	9.3826752	.001210654
827	683929	565609283	28.7576077	9.3864600	.001209190
828	685584	567663552	28.7749891	9.3902419	.001207729
829	687241	569722789	28.7923601	9.3940206	.001206273
830	688900	571787000	28.8097206	9.3977964	.001204819
831	690561	573856191	28.8270706	9.4015691	.001203369
832	692224	575930368	28.8444102	9.4053387	.001201923
833	693889	578009537	28.8617394	9.4091054	.001200480
834	695556	580093704	28.8790582	9.4128690	.001199041
835	697225	582182875	28.8963666	9.4166297	.001197605
836	698896	584277056	28.9136646	9.4203873	.001196172
837	700569	586376233	28.9309523	9.4241420	.001194743
838	702244	588480472	28.9482297	9.4278936	.001193317
839	703921	590589719	28.9654967	9.4316423	.001191895
840	705600	592704000	28.9827535	9.4353880	.001190476
841	707281	594823321	29.0000000	9.4391307	.001189061
842	708964	596947688	29.0172363	9.4428704	.001187648
843	710649	599077107	29.0344623	9.4466072	.001186240
844	712336	601211584	29.0516781	9.4503410	.001184834
845	714025	603351125	29.0688837	9.4540719	.001183432
846	715716	605495736	29.0860791	9.4577999	.001182033
847	717409	607645423	29.1032644	9.4615249	.001180638
848	719104	609800192	29.1204396	9.4652470	.001179245
849	720801	611960049	29.1376046	9.4689661	.001177856
850	722500	614125000	29.1547595	9.4726824	.001176471
851	724201	616295051	29.1719043	9.4763957	.001175088
852	725904	618470208	29.1890390	9.4801061	.001173709
853	727609	620650477	29.2061637	9.4838136	.001172333
854	729316	622835864	29.2232784	9.4875182	.001170960
855	731025	625026375	29.2403830	9.4912200	.001169591
856	732736	627222016	29.2574777	9.4949188	.001168224
857	734449	629422793	29.2745623	9.4986147	.001166861
858	736164	631628712	29.2916370	9.5023078	.001165501
859	737881	633839779	29.3087018	9.5059980	.001164144
860	739600	636056000	29.3257566	9.5096854	.001162791
861	741321	638277331	29.3428015	9.5133699	.001161440
862	743044	640503928	29.3598365	9.5170515	.001160093
863	744769	642735647	29.3768616	9.5207303	.001158749
864	746496	644972544	29.3938769	9.5244063	.001157407
865	748225	647214625	29.4108823	9.5280794	.001156069
866	749956	649461896	29.4278779	9.5317497	.001154734
867	751689	651714363	29.4448637	9.5354172	.001153403
868	753424	653972032	29.4618397	9.5390818	.001152074

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocal.
869	755161	656234909	29.4788059	9.5427437	.001150748
870	756900	658503000	29.4957624	9.5464027	.001149425
871	758641	660776311	29.5127091	9.5500589	.001148106
872	760384	663054848	29.5296461	9.5537123	.001146789
873	762129	665338617	29.5465734	9.5573630	.001145475
874	763876	667627624	29.5634910	9.5610108	.001144165
875	765625	669921875	29.5803989	9.5646559	.001142857
876	767376	672221376	29.5972972	9.5682982	.001141553
877	769129	674526133	29.6141858	9.5719377	.001140251
878	770884	676836152	29.6310648	9.5755745	.001138952
879	772641	679151439	29.6479342	9.5792085	.001137656
880	774400	681472000	29.6647939	9.5828397	.001136364
881	776161	683797841	29.6816442	9.5864682	.001135074
882	777924	686128968	29.6984848	9.5900939	.001133787
883	779689	688465387	29.7153159	9.5937169	.001132503
884	781456	690807104	29.7321375	9.5973373	.001131222
885	783225	693154125	29.7489496	9.6009548	.001129944
886	784996	695506456	29.7657521	9.6045696	.001128668
887	786769	697864103	29.7825452	9.6081817	.001127396
888	788544	700227072	29.7993289	9.6117911	.001126126
889	790321	702595369	29.8161030	9.6153977	.001124859
890	792100	704969000	29.8328678	9.6190017	.001123596
891	793881	707347971	29.8496231	9.6226030	.001122334
892	795664	709732288	29.8663690	9.6262016	.001121076
893	797449	712121957	29.8831056	9.6297975	.001119821
894	799236	714516984	29.8998328	9.6333907	.001118568
895	801025	716917375	29.9165506	9.6369812	.001117318
896	802816	719323136	29.9332591	9.6405690	.001116071
897	804609	721734273	29.9499583	9.6441542	.001114827
898	806404	724150792	29.9666481	9.6477367	.001113586
899	808201	726572699	29.9833287	9.6513166	.001112347
900	810000	729000000	30.0000000	9.6548938	.001111111
901	811801	731432701	30.0166620	9.6584684	.001109878
902	813604	733870808	30.0333148	9.6620403	.001108647
903	815409	736314327	30.0499584	9.6656096	.001107420
904	817216	738763264	30.0665928	9.6691762	.001106195
905	819025	741217625	30.0832179	9.6727403	.001104972
906	820836	743677416	30.0998339	9.6763017	.001103753
907	822649	746142643	30.1164407	9.6798604	.001102536
908	824464	748613312	30.1330383	9.6834166	.001101322
909	826281	751089429	30.1496269	9.6869701	.001100110
910	828100	753571000	30.1662063	9.6905211	.001098901
911	829921	756058031	30.1827765	9.6940694	.001097695
912	831744	758550528	30.1993377	9.6976151	.001096491
913	833569	761048497	30.2158899	9.7011583	.001095290
914	835396	763551944	30.2324329	9.7046989	.001094092
915	837225	766060875	30.2489669	9.7082369	.001092896
916	839056	768575296	30.2654919	9.7117723	.001091703
917	840889	771095213	30.2820079	9.7153051	.001090513
918	842724	773620632	30.2985148	9.7188354	.001089325
919	844561	776151559	30.3150128	9.7223631	.001088139
920	846400	778688000	30.3315018	9.7258883	.001086957
921	848241	781229961	30.3479818	9.7294109	.001085776
922	850084	783777448	30.3644529	9.7329309	.001084599
923	851929	786330467	30.3809151	9.7364484	.001083424
924	853776	788889024	30.3973683	9.7399634	.001082251
925	855625	791453125	30.4138127	9.7434758	.001081081
926	857476	794022776	30.4302481	9.7469857	.001079914
927	859329	796597983	30.4466747	9.7504930	.001078749
928	861184	799178752	30.4630924	9.7539979	.001077586
929	863041	801765089	30.4795013	9.7575002	.001076426
930	864900	804357000	30.4959014	9.7610001	.001075269

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
931	866761	806954491	30.5122926	9.7644974	.001074114
932	868624	809557568	30.5286750	9.7679922	.001072961
933	870489	812166237	30.5450487	9.7714845	.001071811
934	872356	814780504	30.5614136	9.7749743	.001070664
935	874225	817400375	30.5777697	9.7784616	.001069519
936	876096	820025856	30.5941171	9.7819466	.001068376
937	877969	822656953	30.6104557	9.7854288	.001067236
938	879844	825293672	30.6267857	9.7889087	.001066098
939	881721	827936019	30.6431069	9.7923861	.001064963
940	883600	830584000	30.6594194	9.7958611	.001063830
941	885481	833237621	30.6757233	9.7993336	.001062699
942	887364	835896888	30.6920185	9.8028036	.001061571
943	889249	838561807	30.7083051	9.8062711	.001060445
944	891136	841232384	30.7245830	9.8097362	.001059322
945	893025	843908625	30.7408523	9.8131989	.001058201
946	894916	846590536	30.7571130	9.8166591	.001057082
947	896809	849278123	30.7733651	9.8201169	.001055966
948	898704	851971392	30.7896086	9.8235723	.001054852
949	900601	854670349	30.8058436	9.8270252	.001053741
950	902500	857375000	30.8220700	9.8304757	.001052632
951	904401	860085351	30.8382879	9.8339238	.001051525
952	906304	862801408	30.8544972	9.8373695	.001050420
953	908209	865523177	30.8706981	9.8408127	.001049318
954	910116	868250664	30.8868904	9.8442536	.001048218
955	912025	870983875	30.9030743	9.8476920	.001047120
956	913936	873722816	30.9192497	9.8511280	.001046025
957	915849	876467493	30.9354166	9.8545617	.001044932
958	917764	879217912	30.9515751	9.8579929	.001043841
959	919681	881974079	30.9677251	9.8614218	.001042753
960	921600	884736000	30.9838668	9.8648483	.001041667
961	923521	887503681	31.0000000	9.8682724	.001040583
962	925444	890277128	31.0161248	9.8716941	.001039501
963	927369	893056347	31.0322413	9.8751135	.001038422
964	929296	895841344	31.0483494	9.8785305	.001037344
965	931225	898632125	31.0644441	9.8819451	.001036269
966	933156	901428696	31.0805405	9.8853574	.001035197
967	935089	904231063	31.0966236	9.8887673	.001034126
968	937024	907039232	31.1126984	9.8921749	.001033058
969	938961	909853209	31.1287648	9.8955801	.001031992
970	940900	912673000	31.1448230	9.8989830	.001030928
971	942841	915498611	31.1608729	9.9023835	.001029866
972	944784	918330048	31.1769145	9.9057817	.001028807
973	946729	921167317	31.1929479	9.9091776	.001027749
974	948676	924010424	31.2089731	9.9125712	.001026694
975	950625	926859375	31.2249900	9.9159624	.001025641
976	952576	929714176	31.2409987	9.9193513	.001024590
977	954529	932574833	31.2569992	9.9227379	.001023541
978	956484	935441352	31.2729915	9.9261222	.001022495
979	958441	938313739	31.2889757	9.9295042	.001021450
980	960400	941192000	31.3049517	9.9328839	.001020408
981	962361	944076141	31.3209195	9.9362613	.001019368
982	964324	946966168	31.3368792	9.9396363	.001018330
983	966289	949862087	31.3528308	9.9430092	.001017294
984	968256	952763904	31.3687743	9.9463797	.001016260
985	970225	955671625	31.3847097	9.9497479	.001015228
986	972196	958585256	31.4006369	9.9531138	.001014199
987	974169	961504803	31.4165561	9.9564775	.001013171
988	976144	964430272	31.4324673	9.9598389	.001012146
989	978121	967361669	31.4483704	9.9631981	.001011122
990	980100	970299000	31.4642654	9.9665549	.001010101
991	982081	973242271	31.4801525	9.9699095	.001009082
992	984064	976191488	31.4960315	9.9732619	.001008065

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
993	986049	979146657	31.5119025	9.9766120	.001007049
994	988036	982107784	31.5277655	9.9799599	.001006036
995	990025	985074875	31.5436206	9.9833055	.001005025
996	992016	988047936	31.5594677	9.9866488	.001004016
997	994009	991026973	31.5753068	9.9899900	.001003009
998	996004	994011992	31.5911380	9.9933289	.001002004
999	998001	997002999	31.6069613	9.9966656	.001001001
1000	1000000	1000000000	31.6227766	10.0000000	.001000000
1001	1002001	1003003001	31.6385840	10.0033322	.0009990010
1002	1004004	1006012008	31.6543836	10.0066622	.0009980040
1003	1006009	1009027027	31.6701752	10.0099899	.0009970090
1004	1008016	1012048064	31.6859590	10.0133155	.0009960159
1005	1010025	1015075125	31.7017349	10.0166389	.0009950249
1006	1012036	1018108216	31.7175030	10.0199601	.0009940358
1007	1014049	1021147343	31.7332633	10.0232791	.0009930487
1008	1016064	1024192512	31.7490157	10.0265958	.0009920635
1009	1018081	1027243729	31.7647603	10.0299104	.0009910803
1010	1020100	1030301000	31.7804972	10.0332228	.0009900990
1011	1022121	1033364331	31.7962262	10.0365330	.0009891197
1012	1024144	1036433728	31.8119474	10.0398410	.0009881423
1013	1026169	1039509197	31.8276609	10.0431469	.0009871668
1014	1028196	1042590744	31.8433666	10.0464506	.0009861933
1015	1030225	1045678375	31.8590646	10.0497521	.0009852217
1016	1032256	1048772096	31.8747549	10.0530514	.0009842520
1017	1034289	1051871913	31.8904374	10.0563485	.0009832842
1018	1036324	1054977832	31.9061123	10.0596435	.0009823183
1019	1038361	1058039859	31.9217794	10.0629364	.0009813543
1020	1040400	1061208000	31.9374388	10.0662271	.0009803922
1021	1042441	1064332261	31.9530906	10.0695156	.0009794319
1022	1044484	1067462648	31.9687347	10.0728020	.0009784736
1023	1046529	1070599167	31.9843712	10.0760863	.0009775171
1024	1048576	1073741824	32.0000000	10.0793684	.0009765625
1025	1050625	1076890625	32.0156212	10.0826484	.0009756098
1026	1052676	1080045576	32.0312348	10.0859262	.0009746589
1027	1054729	1083206683	32.0468407	10.0892019	.0009737098
1028	1056784	1086373952	32.0624391	10.0924755	.0009727626
1029	1058841	1089547389	32.0780298	10.0957469	.0009718173
1030	1060900	1092727000	32.0936131	10.0990163	.0009708738
1031	1062961	1095912791	32.1091887	10.1022835	.0009699321
1032	1065024	1099104768	32.1247568	10.1055487	.0009689922
1033	1067089	1102302937	32.1403173	10.1088117	.0009680542
1034	1069156	1105507304	32.1558704	10.1120726	.0009671180
1035	1071225	1108717875	32.1714159	10.1153314	.0009661836
1036	1073296	1111934656	32.1869539	10.1185882	.0009652510
1037	1075369	1115157653	32.2024844	10.1218428	.0009643202
1038	1077444	1118386872	32.2180074	10.1250953	.0009633911
1039	1079521	1121623319	32.2335229	10.1283457	.0009624639
1040	1081600	1124864000	32.2490310	10.1315941	.0009615385
1041	1083681	1128111921	32.2645316	10.1348403	.0009606148
1042	1085764	1131366088	32.2800248	10.1380845	.0009596929
1043	1087849	1134626507	32.2955105	10.1413266	.0009587728
1044	1089936	1137893184	32.3109888	10.1445667	.0009578544
1045	1092025	1141166125	32.3264598	10.1478047	.0009569378
1046	1094116	1144445236	32.3419223	10.1510406	.0009560229
1047	1096209	1147730823	32.3573794	10.1542744	.0009551098
1048	1098304	1151022592	32.3728281	10.1575062	.0009541985
1049	1100401	1154320649	32.3882695	10.1607359	.0009532888
1050	1102500	1157625000	32.4037035	10.1639636	.0009523810
1051	1104601	1160935651	32.4191301	10.1671893	.0009514748
1052	1106704	1164252608	32.4345495	10.1704129	.0009505703
1053	1108809	1167575877	32.4499615	10.1736344	.0009496676
1054	1110916	1170905464	32.4653662	10.1768539	.0009487666

No. 100 L. 000.]

[No. 109 L. 040.]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
100	000000	0434	0868	1301	1734	2166	2598	3029	3461	3891	432
1	4321	4751	5181	5609	6038	6466	6894	7321	7748	8174	428
2	8600	9026	9451	9876							
3	012837	3259	3680	4100	0800	0724	1147	1570	1993	2415	424
4	7033	7451	7868	8284	4521	4940	5360	5779	6197	6616	420
					8700	9116	9532	9947			
5	021189	1603	2016	2428	2841	3252	3664	4075	0361	0775	416
6	5306	5715	6125	6533	6942	7350	7757	8164	4486	4896	412
7	9384	9789							8571	8978	408
8	033424	3826	0195	0600	1004	1408	1812	2216	2619	3021	404
9	7426	7825	4227	4628	5029	5430	5830	6230	6629	7028	400
	04		8223	8620	9017	9414	9811				
								0207	0602	0998	397

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
434	43.4	86.8	130.2	173.6	217.0	260.4	303.8	347.2	390.6
433	43.3	86.6	129.9	173.2	216.5	259.8	303.1	346.4	389.7
432	43.2	86.4	129.6	172.8	216.0	259.2	302.4	345.6	388.8
431	43.1	86.2	129.3	172.4	215.5	258.6	301.7	344.8	387.9
430	43.0	86.0	129.0	172.0	215.0	258.0	301.0	344.0	387.0
429	42.9	85.8	128.7	171.6	214.5	257.4	300.3	343.2	386.1
428	42.8	85.6	128.4	171.2	214.0	256.8	299.6	342.4	385.2
427	42.7	85.4	128.1	170.8	213.5	256.2	298.9	341.6	384.3
426	42.6	85.2	127.8	170.4	213.0	255.6	298.2	340.8	383.4
425	42.5	85.0	127.5	170.0	212.5	255.0	297.5	340.0	382.5
424	42.4	84.8	127.2	169.6	212.0	254.4	296.8	339.2	381.6
423	42.3	84.6	126.9	169.2	211.5	253.8	296.1	338.4	380.7
422	42.2	84.4	126.6	168.8	211.0	253.2	295.4	337.6	379.8
421	42.1	84.2	126.3	168.4	210.5	252.6	294.7	336.8	378.9
420	42.0	84.0	126.0	168.0	210.0	252.0	294.0	336.0	378.0
419	41.9	83.8	125.7	167.6	209.5	251.4	293.3	335.2	377.1
418	41.8	83.6	125.4	167.2	209.0	250.8	292.6	334.4	376.2
417	41.7	83.4	125.1	166.8	208.5	250.2	291.9	333.6	375.3
416	41.6	83.2	124.8	166.4	208.0	249.6	291.2	332.8	374.4
415	41.5	83.0	124.5	166.0	207.5	249.0	290.5	332.0	373.5
414	41.4	82.8	124.2	165.6	207.0	248.4	289.8	331.2	372.6
413	41.3	82.6	123.9	165.2	206.5	247.8	289.1	330.4	371.7
412	41.2	82.4	123.6	164.8	206.0	247.2	288.4	329.6	370.8
411	41.1	82.2	123.3	164.4	205.5	246.6	287.7	328.8	369.9
410	41.0	82.0	123.0	164.0	205.0	246.0	287.0	328.0	369.0
409	40.9	81.8	122.7	163.6	204.5	245.4	286.3	327.2	368.1
408	40.8	81.6	122.4	163.2	204.0	244.8	285.6	326.4	367.2
407	40.7	81.4	122.1	162.8	203.5	244.2	284.9	325.6	366.3
406	40.6	81.2	121.8	162.4	203.0	243.6	284.2	324.8	365.4
405	40.5	81.0	121.5	162.0	202.5	243.0	283.5	324.0	364.5
404	40.4	80.8	121.2	161.6	202.0	242.4	282.8	323.2	363.6
403	40.3	80.6	120.9	161.2	201.5	241.8	282.1	322.4	362.7
402	40.2	80.4	120.6	160.8	201.0	241.2	281.4	321.6	361.8
401	40.1	80.2	120.3	160.4	200.5	240.6	280.7	320.8	360.9
400	40.0	80.0	120.0	160.0	200.0	240.0	280.0	320.0	360.0
399	39.9	79.8	119.7	159.6	199.5	239.4	279.3	319.2	359.1
398	39.8	79.6	119.4	159.2	199.0	238.8	278.6	318.4	358.2
397	39.7	79.4	119.1	158.8	198.5	238.2	277.9	317.6	357.3
396	39.6	79.2	118.8	158.4	198.0	237.6	277.2	316.8	356.4
395	39.5	79.0	118.5	158.0	197.5	237.0	276.5	316.0	355.5

No. 110 L. 041.]

[No. 119 L. 078.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
110	041393	1787	2182	2576	2969	3362	3755	4148	4540	4932	393
1	5323	5714	6105	6495	6885	7275	7664	8053	8442	8830	390
2	9218	9606	9993								
3	053078	3463	3846	4230	4613	4996	5378	5760	6142	6524	386
4	6905	7286	7666	8046	8426	8805	9185	9563	9942		383
5	060698	1075	1452	1829	2206	2582	2958	3333	3709	4083	379
6	4458	4832	5206	5580	5953	6326	6699	7071	7443	7815	376
7	8186	8557	8928	9298	9668						373
8	071882	2250	2617	2985	3352	0038	0407	0776	1145	1514	370
9	5547	5912	6276	6640	7004	3718	4085	4451	4816	5182	366
						7368	7731	8094	8457	8819	363

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
395	39.5	79.0	118.5	158.0	197.5	237.0	276.5	316.0	355.5
394	39.4	78.8	118.2	157.6	197.0	236.4	275.8	315.2	354.6
393	39.3	78.6	117.9	157.2	196.5	235.8	275.1	314.4	353.7
392	39.2	78.4	117.6	156.8	196.0	235.2	274.4	313.6	352.8
391	39.1	78.2	117.3	156.4	195.5	234.6	273.7	312.8	351.9
390	39.0	78.0	117.0	156.0	195.0	234.0	273.0	312.0	351.0
389	38.9	77.8	116.7	155.6	194.5	233.4	272.3	311.2	350.1
388	38.8	77.6	116.4	155.2	194.0	232.8	271.6	310.4	349.2
387	38.7	77.4	116.1	154.8	193.5	232.2	270.9	309.6	348.3
386	38.6	77.2	115.8	154.4	193.0	231.6	270.2	308.8	347.4
385	38.5	77.0	115.5	154.0	192.5	231.0	269.5	308.0	346.5
384	38.4	76.8	115.2	153.6	192.0	230.4	268.8	307.2	345.6
383	38.3	76.6	114.9	153.2	191.5	229.8	268.1	306.4	344.7
382	38.2	76.4	114.6	152.8	191.0	229.2	267.4	305.6	343.8
381	38.1	76.2	114.3	152.4	190.5	228.6	266.7	304.8	342.9
380	38.0	76.0	114.0	152.0	190.0	228.0	266.0	304.0	342.0
379	37.9	75.8	113.7	151.6	189.5	227.4	265.3	303.2	341.1
378	37.8	75.6	113.4	151.2	189.0	226.8	264.6	302.4	340.2
377	37.7	75.4	113.1	150.8	188.5	226.2	263.9	301.6	339.3
376	37.6	75.2	112.8	150.4	188.0	225.6	263.2	300.8	338.4
375	37.5	75.0	112.5	150.0	187.5	225.0	262.5	300.0	337.5
374	37.4	74.8	112.2	149.6	187.0	224.4	261.8	299.2	336.6
373	37.3	74.6	111.9	149.2	186.5	223.8	261.1	298.4	335.7
372	37.2	74.4	111.6	148.8	186.0	223.2	260.4	297.6	334.8
371	37.1	74.2	111.3	148.4	185.5	222.6	259.7	296.8	333.9
370	37.0	74.0	111.0	148.0	185.0	222.0	259.0	296.0	333.0
369	36.9	73.8	110.7	147.6	184.5	221.4	258.3	295.2	332.1
368	36.8	73.6	110.4	147.2	184.0	220.8	257.6	294.4	331.2
367	36.7	73.4	110.1	146.8	183.5	220.2	256.9	293.6	330.3
366	36.6	73.2	109.8	146.4	183.0	219.6	256.2	292.8	329.4
365	36.5	73.0	109.5	146.0	182.5	219.0	255.7	292.0	328.5
364	36.4	72.8	109.2	145.6	182.0	218.4	254.8	291.2	327.6
363	36.3	72.6	108.9	145.2	181.5	217.8	254.1	290.4	326.7
362	36.2	72.4	108.6	144.8	181.0	217.2	253.4	289.6	325.8
361	36.1	72.2	108.3	144.4	180.5	216.6	252.7	288.8	324.9
360	36.0	72.0	108.0	144.0	180.0	216.0	252.0	288.0	324.0
359	35.9	71.8	107.7	143.6	179.5	215.4	251.3	287.2	323.1
358	35.8	71.6	107.4	143.2	179.0	214.8	250.6	286.4	322.2
357	35.7	71.4	107.1	142.8	178.5	214.2	249.9	285.6	321.3
356	35.6	71.2	106.8	142.4	178.0	213.6	249.2	284.8	320.4

No. 120 L. 079.]

[No. 184 L. 180.]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
120	079181	9543	9904								
1	082785	3144	3503	0266	0626	0987	1347	1707	2067	2426	360
2	6360	6716	7071	3361	4219	4576	4934	5291	5647	6004	357
3	9905			7426	7781	8136	8490	8845	9198	9552	355
4	093422	0258	0611	0963	1315	1667	2018	2370	2721	3071	352
5	6910	3772	4122	4471	4820	5169	5518	5866	6215	6562	349
6		7257	7604	7951	8298	8644	8990	9335	9681		
7	100371	0715	1059	1403	1747	2091	2434	2777	3119	0026	346
8	3804	4146	4487	4828	5169	5510	5851	6191	6531	3462	343
9	7210	7549	7888	8227	8565	8903	9241	9579	9916	6871	341
130	110590	0926	1263	1599	1934	2270	2605	2940	3275	0253	338
1	3943	4277	4611	4944	5278	5611	5943	6276	6608	3609	335
2	7271	7603	7934	8265	8595	8926	9256	9586	9915	6940	333
3	120574	0903	1231	1560	1888	2216	2544	2871	3198	0245	330
4	3852	4178	4504	4830	5156	5481	5806	6131	6456	3525	328
13	7105	7429	7753	8076	8399	8722	9045	9368	9690	6781	325
										0012	323

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
355	35.5	71.0	106.5	142.0	177.5	213.0	248.5	284.0	319.5
354	35.4	70.8	106.2	141.6	177.0	212.4	247.8	283.2	318.6
353	35.3	70.6	105.9	141.2	176.5	211.8	247.1	282.4	317.7
352	35.2	70.4	105.6	140.8	176.0	211.2	246.4	281.6	316.8
351	35.1	70.2	105.3	140.4	175.5	210.6	245.7	280.8	315.9
350	35.0	70.0	105.0	140.0	175.0	210.0	245.0	280.0	315.0
349	34.9	69.8	104.7	139.6	174.5	209.4	244.3	279.2	314.1
348	34.8	69.6	104.4	139.2	174.0	208.8	243.6	278.4	313.2
347	34.7	69.4	104.1	138.8	173.5	208.2	242.9	277.6	312.3
346	34.6	69.2	103.8	138.4	173.0	207.6	242.2	276.8	311.4
345	34.5	69.0	103.5	138.0	172.5	207.0	241.5	276.0	310.5
344	34.4	68.8	103.2	137.6	172.0	206.4	240.8	275.2	309.6
343	34.3	68.6	102.9	137.2	171.5	205.8	240.1	274.4	308.7
342	34.2	68.4	102.6	136.8	171.0	205.2	239.4	273.6	307.8
341	34.1	68.2	102.3	136.4	170.5	204.6	238.7	272.8	306.9
340	34.0	68.0	102.0	136.0	170.0	204.0	238.0	272.0	306.0
339	33.9	67.8	101.7	135.6	169.5	203.4	237.3	271.2	305.1
338	33.8	67.6	101.4	135.2	169.0	202.8	236.6	270.4	304.2
337	33.7	67.4	101.1	134.8	168.5	202.2	235.9	269.6	303.3
336	33.6	67.2	100.8	134.4	168.0	201.6	235.2	268.8	302.4
335	33.5	67.0	100.5	134.0	167.5	201.0	234.5	268.0	301.5
334	33.4	66.8	100.2	133.6	167.0	200.4	233.8	267.2	300.6
333	33.3	66.6	99.9	133.2	166.5	199.8	233.1	266.4	299.7
332	33.2	66.4	99.6	132.8	166.0	199.2	232.4	265.6	298.8
331	33.1	66.2	99.3	132.4	165.5	198.6	231.7	264.8	297.9
330	33.0	66.0	99.0	132.0	165.0	198.0	231.0	264.0	297.0
329	32.9	65.8	98.7	131.6	164.5	197.4	230.3	263.2	296.1
328	32.8	65.6	98.4	131.2	164.0	196.8	229.6	262.4	295.2
327	32.7	65.4	98.1	130.8	163.5	196.2	228.9	261.6	294.3
326	32.6	65.2	97.8	130.4	163.0	195.6	228.2	260.8	293.4
325	32.5	65.0	97.5	130.0	162.5	195.0	227.5	260.0	292.5
324	32.4	64.8	97.2	129.6	162.0	194.4	226.8	259.2	291.6
323	32.3	64.6	96.9	129.2	161.5	193.8	226.1	258.4	290.7
322	32.2	64.4	96.6	128.8	161.0	193.2	225.4	257.6	289.8

No. 135 L. 130.]

[No. 149 L. 175.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
135	130334	0655	0977	1298	1619	1939	2260	2580	2900	3219	321
6	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403	318
7	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564	316
8	9879										
9	143015	0194	0508	0822	1136	1450	1763	2076	2389	2702	314
140	6128	6438	6748	7058	7367	7676	7985	8294	8603	8911	309
1	9219	9527	9835								
2	152288	2594	2900	3205	3510	3815	4120	4424	4728	5032	307
3	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	305
4	8362	8664	8965	9266	9567	9868					303
5	161368	1667	1967	2266	2564	2863	3161	3460	3758	4055	301
6	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	299
7	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	297
8	170262	0555	0848	1141	1434	1726	2019	2311	2603	2895	295
9	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
321	32.1	64.2	96.3	128.4	160.5	192.6	224.7	256.8	288.9
320	32.0	64.0	96.0	128.0	160.0	192.0	224.0	256.0	288.0
319	31.9	63.8	95.7	127.6	159.5	191.4	223.3	255.2	287.1
318	31.8	63.6	95.4	127.2	159.0	190.8	222.6	254.4	286.2
317	31.7	63.4	95.1	126.8	158.5	190.2	221.9	253.6	285.3
316	31.6	63.2	94.8	126.4	158.0	189.6	221.2	252.8	284.4
315	31.5	63.0	94.5	126.0	157.5	189.0	220.5	252.0	283.5
314	31.4	62.8	94.2	125.6	157.0	188.4	219.8	251.2	282.6
313	31.3	62.6	93.9	125.2	156.5	187.8	219.1	250.4	281.7
312	31.2	62.4	93.6	124.8	156.0	187.2	218.4	249.6	280.8
311	31.1	62.2	93.3	124.4	155.5	186.6	217.7	248.8	279.9
310	31.0	62.0	93.0	124.0	155.0	186.0	217.0	248.0	279.0
309	30.9	61.8	92.7	123.6	154.5	185.4	216.3	247.2	278.1
308	30.8	61.6	92.4	123.2	154.0	184.8	215.6	246.4	277.2
307	30.7	61.4	92.1	122.8	153.5	184.2	214.9	245.6	276.3
306	30.6	61.2	91.8	122.4	153.0	183.6	214.2	244.8	275.4
305	30.5	61.0	91.5	122.0	152.5	183.0	213.5	244.0	274.5
304	30.4	60.8	91.2	121.6	152.0	182.4	212.8	243.2	273.6
303	30.3	60.6	90.9	121.2	151.5	181.8	212.1	242.4	272.7
302	30.2	60.4	90.6	120.8	151.0	181.2	211.4	241.6	271.8
301	30.1	60.2	90.3	120.4	150.5	180.6	210.7	240.8	270.9
300	30.0	60.0	90.0	120.0	150.0	180.0	210.0	240.0	270.0
299	29.9	59.8	89.7	119.6	149.5	179.4	209.3	239.2	269.1
298	29.8	59.6	89.4	119.2	149.0	178.8	208.6	238.4	268.2
297	29.7	59.4	89.1	118.8	148.5	178.2	207.9	237.6	267.3
296	29.6	59.2	88.8	118.4	148.0	177.6	207.2	236.8	266.4
295	29.5	59.0	88.5	118.0	147.5	177.0	206.5	236.0	265.5
294	29.4	58.8	88.2	117.6	147.0	176.4	205.8	235.2	264.6
293	29.3	58.6	87.9	117.2	146.5	175.8	205.1	234.4	263.7
292	29.2	58.4	87.6	116.8	146.0	175.2	204.4	233.6	262.8
291	29.1	58.2	87.3	116.4	145.5	174.6	203.7	232.8	261.9
290	29.0	58.0	87.0	116.0	145.0	174.0	203.0	232.0	261.0
289	28.9	57.8	86.7	115.6	144.5	173.4	202.3	231.2	260.1
288	28.8	57.6	86.4	115.2	144.0	172.8	201.6	230.4	259.2
287	28.7	57.4	86.1	114.8	143.5	172.2	200.9	229.6	258.3
286	28.6	57.2	85.8	114.4	143.0	171.6	200.2	228.8	257.4

No. 150 L. 176.]

[No. 169 L. 230.]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
150	176091	6381	6670	6959	7248	7536	7825	8113	8401	8689	289
1	8977	9264	9552	9839							
					0126	0413	0699	0986	1272	1558	287
2	181844	2129	2415	2700	2985	3270	3555	3839	4123	4407	285
3	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
4	7521	7803	8084	8366	8647	8928	9209	9490	9771		
										0051	281
5	190332	0612	0892	1171	1451	1730	2010	2289	2567	2846	279
6	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
7	5900	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
8	8657	8932	9206	9481	9755						
						0029	0308	0577	0850	1124	274
9	201397	1670	1943	2216	2488	2761	3033	3305	3577	3848	272
160	4120	4391	4663	4934	5204	5475	5746	6016	6286	6556	271
1	6826	7096	7365	7634	7904	8173	8441	8710	8979	9247	269
2	9515	9783									
			0051	0319	0586	0853	1121	1388	1654	1921	267
3	212188	2454	2720	2986	3252	3518	3783	4049	4314	4579	266
4	4844	5109	5373	5638	5902	6166	6430	6694	6957	7221	264
5	7484	7747	8010	8273	8536	8798	9060	9323	9585	9846	262
6	220108	0370	0631	0892	1153	1414	1675	1936	2196	2456	261
7	2716	2976	3236	3496	3755	4015	4274	4533	4792	5051	259
8	5309	5568	5826	6084	6342	6600	6858	7115	7372	7630	258
9	7887	8144	8400	8657	8913	9170	9426	9682	9938		
23										0193	256

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
285	28.5	57.0	85.5	114.0	142.5	171.0	199.5	228.0	256.5
284	28.4	56.8	85.2	113.6	142.0	170.4	198.8	227.2	255.6
283	28.3	56.6	84.9	113.2	141.5	169.8	198.1	226.4	254.7
282	28.2	56.4	84.6	112.8	141.0	169.2	197.4	225.6	253.8
281	28.1	56.2	84.3	112.4	140.5	168.6	196.7	224.8	252.9
280	28.0	56.0	84.0	112.0	140.0	168.0	196.0	224.0	252.0
279	27.9	55.8	83.7	111.6	139.5	167.4	195.3	223.2	251.1
278	27.8	55.6	83.4	111.2	139.0	166.8	194.6	222.4	250.2
277	27.7	55.4	83.1	110.8	138.5	166.2	193.9	221.6	249.3
276	27.6	55.2	82.8	110.4	138.0	165.6	193.2	220.8	248.4
275	27.5	55.0	82.5	110.0	137.5	165.0	192.5	220.0	247.5
274	27.4	54.8	82.2	109.6	137.0	164.4	191.8	219.2	246.6
273	27.3	54.6	81.9	109.2	136.5	163.8	191.1	218.4	245.7
272	27.2	54.4	81.6	108.8	136.0	163.2	190.4	217.6	244.8
271	27.1	54.2	81.3	108.4	135.5	162.6	189.7	216.8	243.9
270	27.0	54.0	81.0	108.0	135.0	162.0	189.0	216.0	243.0
269	26.9	53.8	80.7	107.6	134.5	161.4	188.3	215.2	242.1
268	26.8	53.6	80.4	107.2	134.0	160.8	187.6	214.4	241.2
267	26.7	53.4	80.1	106.8	133.5	160.2	186.9	213.6	240.3
266	26.6	53.2	79.8	106.4	133.0	159.6	186.2	212.8	239.4
265	26.5	53.0	79.5	106.0	132.5	159.0	185.5	212.0	238.5
264	26.4	52.8	79.2	105.6	132.0	158.4	184.8	211.2	237.6
263	26.3	52.6	78.9	105.2	131.5	157.8	184.1	210.4	236.7
262	26.2	52.4	78.6	104.8	131.0	157.2	183.4	209.6	235.8
261	26.1	52.2	78.3	104.4	130.5	156.6	182.7	208.8	234.9
260	26.0	52.0	78.0	104.0	130.0	156.0	182.0	208.0	234.0
259	25.9	51.8	77.7	103.6	129.5	155.4	181.3	207.2	233.1
258	25.8	51.6	77.4	103.2	129.0	154.8	180.6	206.4	232.2
257	25.7	51.4	77.1	102.8	128.5	154.2	179.9	205.6	231.3
256	25.6	51.2	76.8	102.4	128.0	153.6	179.2	204.8	230.4
255	25.5	51.0	76.5	102.0	127.5	153.0	178.5	204.0	229.5

No. 170 L. 230.]

[No. 189 L. 278.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
170	230449	0704	0960	1215	1470	1724	1979	2234	2488	2742	255
1	2996	3250	3504	3757	4011	4264	4517	4770	5023	5276	253
2	5528	5781	6033	6285	6537	6789	7041	7292	7544	7795	252
3	8046	8297	8548	8799	9049	9299	9550	9800			
									0050	0300	250
4	240549	0799	1048	1297	1546	1795	2044	2293	2541	2790	249
5	3038	3286	3534	3782	4030	4277	4525	4772	5019	5266	248
6	5513	5759	6006	6252	6499	6745	6991	7237	7482	7728	246
7	7973	8219	8464	8709	8954	9198	9443	9687	9932		
										0176	245
8	250420	0664	0908	1151	1395	1638	1881	2125	2368	2610	243
9	2853	3096	3338	3580	3822	4064	4306	4548	4790	5031	242
180	5273	5514	5755	5996	6237	6477	6718	6958	7198	7439	241
1	7679	7918	8158	8398	8637	8877	9116	9355	9594	9833	239
2	260071	0810	0548	0787	1025	1263	1501	1739	1976	2214	238
3	2451	2688	2925	3162	3399	3636	3873	4109	4346	4582	237
4	4818	5054	5290	5525	5761	5996	6232	6467	6702	6937	235
5	7172	7406	7641	7875	8110	8344	8578	8812	9046	9279	234
6	9518	9746	9980								
				0213	0446	0679	0912	1144	1377	1609	233
7	271842	2074	2306	2538	2770	3001	3233	3464	3696	3927	232
8	4158	4389	4620	4850	5081	5311	5542	5772	6002	6232	230
9	6462	6692	6921	7151	7380	7609	7838	8067	8296	8525	229

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
255	25.5	51.0	76.5	102.0	127.5	153.0	178.5	204.0	229.5
254	25.4	50.8	76.2	101.6	127.0	152.4	177.8	203.2	228.6
253	25.3	50.6	75.9	101.2	126.5	151.8	177.1	202.4	227.7
252	25.2	50.4	75.6	100.8	126.0	151.2	176.4	201.6	226.8
251	25.1	50.2	75.3	100.4	125.5	150.6	175.7	200.8	225.9
250	25.0	50.0	75.0	100.0	125.0	150.0	175.0	200.0	225.0
249	24.9	49.8	74.7	99.6	124.5	149.4	174.3	199.2	224.1
248	24.8	49.6	74.4	99.2	124.0	148.8	173.6	198.4	223.2
247	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3
246	24.6	49.2	73.8	98.4	123.0	147.6	172.2	196.8	221.4
245	24.5	49.0	73.5	98.0	122.5	147.0	171.5	196.0	220.5
244	24.4	48.8	73.2	97.6	122.0	146.4	170.8	195.2	219.6
243	24.3	48.6	72.9	97.2	121.5	145.8	170.1	194.4	218.7
242	24.2	48.4	72.6	96.8	121.0	145.2	169.4	193.6	217.8
241	24.1	48.2	72.3	96.4	120.5	144.6	168.7	192.8	216.9
240	24.0	48.0	72.0	96.0	120.0	144.0	168.0	192.0	216.0
239	23.9	47.8	71.7	95.6	119.5	143.4	167.3	191.2	215.1
238	23.8	47.6	71.4	95.2	119.0	142.8	166.6	190.4	214.2
237	23.7	47.4	71.1	94.8	118.5	142.2	165.9	189.6	213.3
236	23.6	47.2	70.8	94.4	118.0	141.6	165.2	188.8	212.4
235	23.5	47.0	70.5	94.0	117.5	141.0	164.5	188.0	211.5
234	23.4	46.8	70.2	93.6	117.0	140.4	163.8	187.2	210.6
233	23.3	46.6	69.9	93.2	116.5	139.8	163.1	186.4	209.7
232	23.2	46.4	69.6	92.8	116.0	139.2	162.4	185.6	208.8
231	23.1	46.2	69.3	92.4	115.5	138.6	161.7	184.8	207.9
230	23.0	46.0	69.0	92.0	115.0	138.0	161.0	184.0	207.0
229	22.9	45.8	68.7	91.6	114.5	137.4	160.3	183.2	206.1
228	22.8	45.6	68.4	91.2	114.0	136.8	159.6	182.4	205.2
227	22.7	45.4	68.1	90.8	113.5	136.2	158.9	181.6	204.3
226	22.6	45.2	67.8	90.4	113.0	135.6	158.2	180.8	203.4

No. 190 L. 278.]

[No. 214 L. 332.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
190	278754	8982	9211	9439	9667	9895					
							0123	0351	0578	0806	228
1	281033	1261	1488	1715	1942	2169	2396	2622	2849	3075	227
2	3301	3527	3753	3979	4205	4431	4656	4882	5107	5332	226
3	5557	5782	6007	6232	6456	6681	6905	7130	7354	7578	225
4	7802	8026	8249	8473	8696	8920	9143	9366	9589	9812	223
5	290035	0257	0480	0702	0925	1147	1369	1591	1813	2034	222
6	2256	2478	2699	2920	3141	3363	3584	3804	4025	4246	221
7	4466	4687	4907	5127	5347	5567	5787	6007	6226	6446	220
8	6665	6884	7104	7323	7542	7761	7979	8198	8416	8635	219
9	8853	9071	9289	9507	9725	9943					
							0161	0378	0595	0813	218
200	301030	1247	1464	1681	1898	2114	2331	2547	2764	2980	217
1	3196	3412	3628	3844	4059	4275	4491	4706	4921	5136	216
2	5351	5566	5781	5996	6211	6425	6639	6854	7068	7282	215
3	7496	7710	7924	8137	8351	8564	8778	8991	9204	9417	213
4	9630	9843									
			0056	0268	0481	0693	0906	1118	1330	1542	212
5	311754	1966	2177	2389	2600	2812	3023	3234	3445	3656	211
6	3867	4078	4289	4499	4710	4920	5130	5340	5551	5760	210
7	5970	6180	6390	6599	6809	7018	7227	7436	7646	7854	209
8	8063	8272	8481	8689	8898	9106	9314	9522	9730	9938	208
9	320146	0354	0562	0769	0977	1184	1391	1598	1805	2012	207
210	2219	2426	2633	2839	3046	3252	3458	3665	3871	4077	206
1	4282	4488	4694	4899	5105	5310	5516	5721	5926	6131	205
2	6336	6541	6745	6950	7155	7359	7563	7767	7972	8176	204
3	8380	8583	8787	8991	9194	9398	9601	9805			
									0008	0211	203
4	330414	0617	0819	1022	1225	1427	1630	1832	2034	2236	202

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
225	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0	202.5
224	22.4	44.8	67.2	89.6	112.0	134.4	156.8	179.2	201.6
223	22.3	44.6	66.9	89.2	111.5	133.8	156.1	178.4	200.7
222	22.2	44.4	66.6	88.8	111.0	133.2	155.4	177.6	199.8
221	22.1	44.2	66.3	88.4	110.5	132.6	154.7	176.8	198.9
220	22.0	44.0	66.0	88.0	110.0	132.0	154.0	176.0	198.0
219	21.9	43.8	65.7	87.6	109.5	131.4	153.3	175.2	197.1
218	21.8	43.6	65.4	87.2	109.0	130.8	152.6	174.4	196.2
217	21.7	43.4	65.1	86.8	108.5	130.2	151.9	173.6	195.3
216	21.6	43.2	64.8	86.4	108.0	129.6	151.2	172.8	194.4
215	21.5	43.0	64.5	86.0	107.5	129.0	150.5	172.0	193.5
214	21.4	42.8	64.2	85.6	107.0	128.4	149.8	171.2	192.6
213	21.3	42.6	63.9	85.2	106.5	127.8	149.1	170.4	191.7
212	21.2	42.4	63.6	84.8	106.0	127.2	148.4	169.6	190.8
211	21.1	42.2	63.3	84.4	105.5	126.6	147.7	168.8	189.9
210	21.0	42.0	63.0	84.0	105.0	126.0	147.0	168.0	189.0
209	20.9	41.8	62.7	83.6	104.5	125.4	146.3	167.2	188.1
208	20.8	41.6	62.4	83.2	104.0	124.8	145.6	166.4	187.2
207	20.7	41.4	62.1	82.8	103.5	124.2	144.9	165.6	186.3
206	20.6	41.2	61.8	82.4	103.0	123.6	144.2	164.8	185.4
205	20.5	41.0	61.5	82.0	102.5	123.0	143.5	164.0	184.5
204	20.4	40.8	61.2	81.6	102.0	122.4	142.8	163.2	183.6
203	20.3	40.6	60.9	81.2	101.5	121.8	142.1	162.4	182.7
202	20.2	40.4	60.6	80.8	101.0	121.2	141.4	161.6	181.8

No. 215 L. 332.]

[No. 239 L. 380.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
215	332438	2640	2842	3044	3246	3447	3649	3850	4051	4253	202
6	4454	4655	4856	5057	5257	5458	5658	5859	6059	6260	201
7	6460	6660	6860	7060	7260	7459	7659	7858	8058	8257	200
8	8456	8656	8855	9054	9253	9451	9650	9849			
									0047	0246	199
220	340444	0642	0841	1039	1237	1435	1632	1830	2028	2225	198
1	2423	2620	2817	3014	3212	3409	3606	3802	3999	4196	197
2	4392	4589	4785	4981	5178	5374	5570	5766	5962	6157	196
3	6353	6549	6744	6939	7135	7330	7525	7720	7915	8110	195
4	8305	8500	8694	8889	9083	9278	9472	9666	9860		
										0054	194
4	350248	0442	0636	0829	1023	1216	1410	1603	1796	1989	193
5	2183	2375	2568	2761	2954	3147	3339	3532	3724	3916	193
6	4108	4301	4493	4685	4876	5068	5260	5452	5643	5834	192
7	6026	6217	6408	6599	6790	6981	7172	7363	7554	7744	191
8	7935	8125	8316	8506	8696	8886	9076	9266	9456	9646	190
9	9835										
		0025	0215	0404	0593	0783	0972	1161	1350	1539	189
230	361728	1917	2105	2294	2482	2671	2859	3048	3236	3424	188
1	3612	3800	3988	4176	4363	4551	4739	4926	5113	5301	188
2	5488	5675	5862	6049	6236	6423	6610	6796	6983	7169	187
3	7356	7542	7729	7915	8101	8287	8473	8659	8845	9030	186
4	9216	9401	9587	9772	9958						
						0143	0328	0513	0698	0883	185
5	371068	1253	1437	1622	1806	1991	2175	2360	2544	2728	184
6	2912	3096	3280	3464	3647	3831	4015	4198	4382	4565	184
7	4748	4932	5115	5298	5481	5664	5846	6029	6212	6394	183
8	6577	6759	6942	7124	7306	7488	7670	7852	8034	8216	182
9	8398	8580	8761	8943	9124	9306	9487	9668	9849		
38										0030	181

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
202	20.2	40.4	60.6	80.8	101.0	121.2	141.4	161.6	181.8
201	20.1	40.2	60.3	80.4	100.5	120.6	140.7	160.8	180.9
200	20.0	40.0	60.0	80.0	100.0	120.0	140.0	160.0	180.0
199	19.9	39.8	59.7	79.6	99.5	119.4	139.3	159.2	179.1
198	19.8	39.6	59.4	79.2	99.0	118.8	138.6	158.4	178.2
197	19.7	39.4	59.1	78.8	98.5	118.2	137.9	157.6	177.3
196	19.6	39.2	58.8	78.4	98.0	117.6	137.2	156.8	176.4
195	19.5	39.0	58.5	78.0	97.5	117.0	136.5	156.0	175.5
194	19.4	38.8	58.2	77.6	97.0	116.4	135.8	155.2	174.6
193	19.3	38.6	57.9	77.2	96.5	115.8	135.1	154.4	173.7
192	19.2	38.4	57.6	76.8	96.0	115.2	134.4	153.6	172.8
191	19.1	38.2	57.3	76.4	95.5	114.6	133.7	152.8	171.9
190	19.0	38.0	57.0	76.0	95.0	114.0	133.0	152.0	171.0
189	18.9	37.8	56.7	75.6	94.5	113.4	132.3	151.2	170.1
188	18.8	37.6	56.4	75.2	94.0	112.8	131.6	150.4	169.2
187	18.7	37.4	56.1	74.8	93.5	112.2	130.9	149.6	168.3
186	18.6	37.2	55.8	74.4	93.0	111.6	130.2	148.8	167.4
185	18.5	37.0	55.5	74.0	92.5	111.0	129.5	148.0	166.5
184	18.4	36.8	55.2	73.6	92.0	110.4	128.8	147.2	165.6
183	18.3	36.6	54.9	73.2	91.5	109.8	128.1	146.4	164.7
182	18.2	36.4	54.6	72.8	91.0	109.2	127.4	145.6	163.8
181	18.1	36.2	54.3	72.4	90.5	108.6	126.7	144.8	162.9
180	18.0	36.0	54.0	72.0	90.0	108.0	126.0	144.0	162.0
179	17.9	35.8	53.7	71.6	89.5	107.4	125.3	143.2	161.1

No. 240 L. 380.]

[No. 269 L. 431.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
240	380211	0392	0573	0754	0934	1115	1296	1476	1656	1837	181
1	2017	2197	2377	2557	2737	2917	3097	3277	3456	3636	180
2	3515	3995	4174	4353	4533	4712	4891	5070	5249	5428	179
3	5606	5785	5964	6142	6321	6499	6677	6856	7034	7212	178
4	7390	7568	7746	7924	8101	8279	8456	8634	8811	8989	178
5	9166	9343	9520	9698	9875						
6	390935	1112	1288	1464	1641	0051	0228	0405	0582	0759	177
7	2697	2873	3048	3224	3400	1817	1993	2169	2345	2521	176
8	4152	4627	4802	4977	5152	3575	3751	3926	4101	4277	176
9	6199	6374	6548	6722	6896	5326	5501	5676	5850	6025	175
250	7940	8114	8287	8461	8634	7071	7245	7419	7592	7766	174
1	9674	9847				8808	8981	9154	9328	9501	173
2	401401	1573	0020	0192	0365	0538	0711	0883	1056	1228	173
3	3121	3292	1745	1917	2089	2261	2433	2605	2777	2949	172
4	4834	5005	3464	3635	3807	3978	4149	4320	4492	4663	171
5	6540	6710	5176	5346	5517	5688	5858	6029	6199	6370	171
6	8240	8410	6881	7051	7221	7391	7561	7731	7901	8070	170
7	9933		8579	8749	8918	9087	9257	9426	9595	9764	169
8	411620	0102	0271	0440	0609	0777	0946	1114	1283	1451	169
9	3300	1788	1956	2124	2293	2461	2629	2796	2964	3132	168
260	4973	5140	3635	3803	3970	4137	4305	4472	4639	4806	167
1	6641	6807	5307	5474	5641	5808	5974	6141	6308	6474	167
2	8301	8467	6973	7139	7306	7472	7638	7804	7970	8135	166
3	9956	8633	8798	8964		9129	9295	9460	9625	9791	165
4	421604	0121	0286	0451	0616	0781	0945	1110	1275	1439	165
5	3246	1768	1933	2097	2261	2426	2590	2754	2918	3082	164
6	4882	3410	3574	3737	3901	4065	4228	4392	4555	4718	164
7	6511	5045	5208	5371	5534	5697	5860	6023	6186	6349	163
8	8135	6674	6836	6999	7161	7324	7486	7648	7811	7973	162
9	9752	8297	8459	8621	8783	8944	9106	9268	9429	9591	162
43		9914	0075	0236	0398	0559	0720	0881	1042	1203	161

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
178	17.8	35.6	53.4	71.2	89.0	106.8	124.6	142.4	160.2
177	17.7	35.4	53.1	70.8	88.5	106.2	123.9	141.6	159.3
176	17.6	35.2	52.8	70.4	88.0	105.6	123.2	140.8	158.4
175	17.5	35.0	52.5	70.0	87.5	105.0	122.5	140.0	157.5
174	17.4	34.8	52.2	69.6	87.0	104.4	121.8	139.2	156.6
173	17.3	34.6	51.9	69.2	86.5	103.8	121.1	138.4	155.7
172	17.2	34.4	51.6	68.8	86.0	103.2	120.4	137.6	154.8
171	17.1	34.2	51.3	68.4	85.5	102.6	119.7	136.8	153.9
170	17.0	34.0	51.0	68.0	85.0	102.0	119.0	136.0	153.0
169	16.9	33.8	50.7	67.6	84.5	101.4	118.3	135.2	152.1
168	16.8	33.6	50.4	67.2	84.0	100.8	117.6	134.4	151.2
167	16.7	33.4	50.1	66.8	83.5	100.2	116.9	133.6	150.3
166	16.6	33.2	49.8	66.4	83.0	99.6	116.2	132.8	149.4
165	16.5	33.0	49.5	66.0	82.5	99.0	115.5	132.0	148.5
164	16.4	32.8	49.2	65.6	82.0	98.4	114.8	131.2	147.6
163	16.3	32.6	48.9	65.2	81.5	97.8	114.1	130.4	146.7
162	16.2	32.4	48.5	64.8	81.0	97.2	113.4	129.6	145.8
161	16.1	32.2	48.3	64.4	80.5	96.6	112.7	128.8	144.9

No. 270 L. 431.]

[No. 299 L. 476.]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
270	431364	1525	1685	1846	2007	2167	2328	2488	2649	2809	161
1	2969	3130	3290	3450	3610	3770	3930	4090	4249	4409	160
2	4569	4729	4888	5048	5207	5367	5526	5685	5844	6004	159
3	6163	6322	6481	6640	6799	6957	7116	7275	7433	7592	159
4	7751	7909	8067	8226	8384	8542	8701	8859	9017	9175	158
5	9333	9491	9648	9806	9964	0122	0279	0437	0594	0752	158
6	440909	1066	1224	1381	1538	1695	1852	2009	2166	2323	157
7	2480	2637	2793	2950	3106	3263	3419	3576	3732	3889	157
8	4045	4201	4357	4513	4669	4825	4981	5137	5293	5449	156
9	5604	5760	5915	6071	6226	6382	6537	6692	6848	7003	155
280	7158	7313	7468	7623	7778	7933	8088	8242	8397	8552	155
1	8706	8861	9015	9170	9324	9478	9633	9787	9941	0095	154
2	450249	0408	0557	0711	0865	1018	1172	1326	1479	1633	154
3	1786	1940	2093	2247	2400	2553	2706	2859	3012	3165	153
4	3318	3471	3624	3777	3930	4082	4235	4387	4540	4692	153
5	4845	4997	5150	5302	5454	5606	5758	5910	6062	6214	152
6	6366	6518	6670	6821	6973	7125	7276	7428	7579	7731	152
7	7882	8033	8184	8336	8487	8638	8789	8940	9091	9242	151
8	9392	9543	9694	9845	9995	0146	0296	0447	0597	0748	151
9	460898	1048	1198	1348	1499	1649	1799	1948	2098	2248	150
290	2398	2548	2697	2847	2997	3146	3296	3445	3594	3744	150
1	3893	4042	4191	4340	4490	4639	4788	4936	5085	5234	149
2	5383	5532	5680	5829	5977	6126	6274	6423	6571	6719	149
3	6868	7016	7164	7312	7460	7608	7756	7904	8052	8200	148
4	8347	8495	8643	8790	8938	9085	9233	9380	9527	9675	148
5	9822	9969	0116	0263	0410	0557	0704	0851	0998	1145	147
6	471292	1438	1585	1732	1878	2025	2171	2318	2464	2610	146
7	2756	2903	3049	3195	3341	3487	3633	3779	3925	4071	146
8	4216	4362	4508	4653	4799	4944	5090	5235	5381	5526	146
9	5671	5816	5962	6107	6252	6397	6542	6687	6832	6976	145

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
161	16.1	32.2	48.3	64.4	80.5	96.6	112.7	128.8	144.9
160	16.0	32.0	48.0	64.0	80.0	96.0	112.0	128.0	144.0
159	15.9	31.8	47.7	63.6	79.5	95.4	111.3	127.2	143.1
158	15.8	31.6	47.4	63.2	79.0	94.8	110.6	126.4	142.2
157	15.7	31.4	47.1	62.8	78.5	94.2	109.9	125.6	141.3
156	15.6	31.2	46.8	62.4	78.0	93.6	109.2	124.8	140.4
155	15.5	31.0	46.5	62.0	77.5	93.0	108.5	124.0	139.5
154	15.4	30.8	46.2	61.6	77.0	92.4	107.8	123.2	138.6
153	15.3	30.6	45.9	61.2	76.5	91.8	107.1	122.4	137.7
152	15.2	30.4	45.6	60.8	76.0	91.2	106.4	121.6	136.8
151	15.1	30.2	45.3	60.4	75.5	90.6	105.7	120.8	135.9
150	15.0	30.0	45.0	60.0	75.0	90.0	105.0	120.0	135.0
149	14.9	29.8	44.7	59.6	74.5	89.4	104.3	119.2	134.1
148	14.8	29.6	44.4	59.2	74.0	88.8	103.6	118.4	133.2
147	14.7	29.4	44.1	58.8	73.5	88.2	102.9	117.6	132.3
146	14.6	29.2	43.8	58.4	73.0	87.6	102.2	116.8	131.4
145	14.5	29.0	43.5	58.0	72.5	87.0	101.5	116.0	130.5
144	14.4	28.8	43.2	57.6	72.0	86.4	100.8	115.2	129.6
143	14.3	28.6	42.9	57.2	71.5	85.8	100.1	114.4	128.7
142	14.2	28.4	42.6	56.8	71.0	85.2	99.4	113.6	127.8
141	14.1	28.2	42.3	56.4	70.5	84.6	98.7	112.8	126.9
140	14.0	28.0	42.0	56.0	70.0	84.0	98.0	112.0	126.0

No. 300 L. 477.]

[No. 339 L. 531.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
300	477121	7266	7411	7555	7700	7844	7989	8133	8278	8422	145
1	8566	8711	8855	8999	9143	9287	9431	9575	9719	9863	144
2	480007	0151	0294	0438	0582	0725	0869	1012	1156	1299	144
3	1443	1586	1729	1872	2016	2159	2302	2445	2588	2731	143
4	2874	3016	3159	3302	3445	3587	3730	3872	4015	4157	143
5	4300	4442	4585	4727	4869	5011	5153	5295	5437	5579	142
6	5721	5863	6005	6147	6289	6430	6572	6714	6855	6997	142
7	7138	7280	7421	7563	7704	7845	7986	8127	8269	8410	141
8	8551	8692	8833	8974	9114	9255	9396	9537	9677	9818	141
9	9958	0099	0239	0380	0520	0661	0801	0941	1081	1222	140
310	491362	1502	1642	1782	1922	2062	2201	2341	2481	2621	140
1	2760	2900	3040	3179	3319	3458	3597	3737	3876	4015	139
2	4155	4294	4433	4572	4711	4850	4989	5128	5267	5406	139
3	5544	5683	5822	5960	6099	6238	6376	6515	6653	6791	139
4	6930	7068	7206	7344	7483	7621	7759	7897	8035	8173	138
5	8311	8448	8586	8724	8862	8999	9137	9275	9412	9550	138
6	9687	9824	9962	0099	0236	0374	0511	0648	0785	0922	137
7	501059	1196	1333	1470	1607	1744	1880	2017	2154	2291	137
8	2427	2564	2700	2837	2973	3109	3246	3382	3518	3655	136
9	3791	3927	4063	4199	4335	4471	4607	4743	4878	5014	136
320	5150	5286	5421	5557	5693	5828	5964	6099	6234	6370	136
1	6505	6640	6776	6911	7046	7181	7316	7451	7586	7721	135
2	7856	7991	8126	8260	8395	8530	8664	8799	8934	9068	135
3	9203	9337	9471	9606	9740	9874	0009	0143	0277	0411	134
4	510545	0679	0813	0947	1081	1215	1349	1482	1616	1750	134
5	1883	2017	2151	2284	2418	2551	2684	2818	2951	3084	133
6	3218	3351	3484	3617	3750	3883	4016	4149	4282	4415	133
7	4548	4681	4813	4946	5079	5211	5344	5476	5609	5741	133
8	5874	6006	6139	6271	6403	6535	6668	6800	6932	7064	132
9	7196	7328	7460	7592	7724	7855	7987	8119	8251	8382	132
330	8514	8646	8777	8909	9040	9171	9303	9434	9566	9697	131
1	9828	9959	0090	0221	0353	0484	0615	0745	0876	1007	131
2	521138	1269	1400	1530	1661	1792	1922	2053	2183	2314	131
3	2444	2575	2705	2835	2966	3096	3226	3356	3486	3616	130
4	3746	3876	4006	4136	4266	4396	4526	4656	4785	4915	130
5	5045	5174	5304	5434	5563	5693	5822	5951	6081	6210	129
6	6339	6469	6598	6727	6856	6985	7114	7243	7372	7501	129
7	7630	7759	7888	8016	8145	8274	8402	8531	8660	8788	129
8	8917	9045	9174	9302	9430	9559	9687	9815	9943	0072	128
9	530200	0328	0456	0584	0712	0840	0968	1096	1223	1351	128

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
139	13.9	27.8	41.7	55.6	69.5	83.4	97.3	111.2	125.1
138	13.8	27.6	41.4	55.2	69.0	82.8	96.6	110.4	124.2
137	13.7	27.4	41.1	54.8	68.5	82.2	95.9	109.6	123.3
136	13.6	27.2	40.8	54.4	68.0	81.6	95.2	108.8	122.4
135	13.5	27.0	40.5	54.0	67.5	81.0	94.5	108.0	121.5
134	13.4	26.8	40.2	53.6	67.0	80.4	93.8	107.2	120.6
133	13.3	26.6	39.9	53.2	66.5	79.8	93.1	106.4	119.7
132	13.2	26.4	39.6	52.8	66.0	79.2	92.4	105.6	118.8
131	13.1	26.2	39.3	52.4	65.5	78.6	91.7	104.8	117.9
130	13.0	26.0	39.0	52.0	65.0	78.0	91.0	104.0	117.0
129	12.9	25.8	38.7	51.6	64.5	77.4	90.3	103.2	116.1
128	12.8	25.6	38.4	51.2	64.0	76.8	89.6	102.4	115.2
127	12.7	25.4	38.1	50.8	63.5	76.2	88.9	101.6	114.3

No. 340 L. 531.]

[No. 379 L. 579.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
340	531479	1607	1734	1862	1990	2117	2245	2372	2500	2627	128
1	2754	2882	3009	3136	3264	3391	3518	3645	3772	3899	127
2	4026	4153	4280	4407	4534	4661	4787	4914	5041	5167	127
3	5294	5421	5547	5674	5800	5927	6053	6180	6306	6432	126
4	6558	6685	6811	6937	7063	7189	7315	7441	7567	7693	126
5	7819	7945	8071	8197	8322	8448	8574	8699	8825	8951	126
6	9076	9202	9327	9452	9578	9703	9829	9954			
7	540329	0455	0580	0705	0830	0955	1080	1205	0079	0204	125
8	1579	1704	1829	1953	2078	2203	2327	2452	1330	1454	125
9	2825	2950	3074	3199	3323	3447	3571	3696	2576	2701	125
350	4068	4192	4316	4440	4564	4688	4812	4936	3820	3944	124
1	5307	5431	5555	5678	5802	5925	6049	6172	5060	5183	124
2	6543	6666	6789	6913	7036	7159	7282	7405	6296	6419	124
3	7775	7898	8021	8144	8267	8389	8512	8635	7529	7652	123
4	9003	9126	9249	9371	9494	9616	9739	9861	8758	8881	123
5	550228	0351	0473	0595	0717	0840	0962	1084	9984	0106	123
6	1450	1572	1694	1816	1938	2060	2181	2303	1206	1328	122
7	2668	2790	2911	3033	3155	3276	3398	3519	2425	2547	122
8	3883	4004	4126	4247	4368	4489	4610	4731	3640	3762	121
9	5094	5215	5336	5457	5578	5699	5820	5940	4852	4973	121
360	6303	6423	6544	6664	6785	6905	7026	7146	6061	6182	121
1	7507	7627	7748	7868	7988	8108	8228	8349	7287	7387	120
2	8709	8829	8948	9068	9188	9308	9428	9548	8469	8589	120
3	9907								9667	9787	120
4	561101	0026	0146	0265	0385	0504	0624	0743	8663	0982	119
5	2293	1221	1340	1459	1578	1698	1817	1936	0863	2055	119
6	3481	2293	2412	2531	2650	2769	2887	3006	2055	2174	119
7	4666	3600	3718	3837	3955	4074	4192	4311	3244	3362	119
8	5848	4784	4903	5021	5139	5257	5376	5494	4429	4548	119
9	7026	5966	6084	6202	6320	6437	6555	6673	5612	5730	118
370	8202	7144	7262	7379	7497	7614	7732	7849	6791	6909	118
1	9374	8319	8436	8554	8671	8788	8905	9023	7967	8084	118
2	570543	9491	9608	9725	9842	9959			9140	9257	117
3	1709						0076	0192	0309	0426	117
4	2872	0660	0776	0893	1010	1126	1243	1359	0476	1592	117
5	4031	1825	1942	2058	2174	2291	2407	2523	1476	1592	117
6	5188	2988	3104	3220	3336	3452	3568	3684	2523	2639	116
7	6341	4147	4263	4379	4494	4610	4726	4841	3684	3800	116
8	7492	5303	5419	5534	5650	5765	5880	5996	4841	4957	116
9	8639	6457	6572	6687	6802	6917	7032	7147	6111	6226	115
		7607	7722	7836	7951	8066	8181	8295	7262	7377	115
		8754	8868	8983	9097	9212	9326	9441	8410	8525	115
									9555	9669	114

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
128	12.8	25.6	38.4	51.2	64.0	76.8	89.6	102.4	115.2
127	12.7	25.4	38.1	50.8	63.5	76.2	88.9	101.6	114.3
126	12.6	25.2	37.8	50.4	63.0	75.6	88.2	100.8	113.4
125	12.5	25.0	37.5	50.0	62.5	75.0	87.5	100.0	112.5
124	12.4	24.8	37.2	49.6	62.0	74.4	86.8	99.2	111.6
123	12.3	24.6	36.9	49.2	61.5	73.8	86.1	98.4	110.7
122	12.2	24.4	36.6	48.8	61.0	73.2	85.4	97.6	109.8
121	12.1	24.2	36.3	48.4	60.5	72.6	84.7	96.8	108.9
120	12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108.0
119	11.9	23.8	35.7	47.6	59.5	71.4	83.3	95.2	107.1

No. 380. L. 579.]

[No. 414 L. 617.]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
380	579784	9896									
			0012	0126	0241	0355	0469	0583	0697	0811	114
1	580925	1039	1153	1267	1381	1495	1608	1722	1836	1950	
2	2063	2177	2291	2404	2518	2631	2745	2858	2972	3085	
3	3199	3312	3426	3539	3652	3765	3879	3992	4105	4218	
4	4331	4444	4557	4670	4783	4896	5009	5122	5235	5348	113
5	5461	5574	5686	5799	5912	6024	6137	6250	6362	6475	
6	6587	6700	6812	6925	7037	7149	7262	7374	7486	7599	
7	7711	7823	7935	8047	8160	8272	8384	8496	8608	8720	112
8	8832	8944	9056	9167	9279	9391	9503	9615	9726	9838	
9	9950										
		0061	0173	0284	0396	0507	0619	0730	0842	0953	
390	591065	1176	1287	1399	1510	1621	1732	1843	1955	2066	
1	2177	2288	2399	2510	2621	2732	2843	2954	3064	3175	111
2	3286	3397	3508	3618	3729	3840	3950	4061	4171	4282	
3	4393	4503	4614	4724	4834	4945	5055	5165	5276	5386	
4	5496	5606	5717	5827	5937	6047	6157	6267	6377	6487	110
5	6597	6707	6817	6927	7037	7146	7256	7366	7476	7586	
6	7695	7805	7914	8024	8134	8243	8353	8462	8572	8681	
7	8791	8900	9009	9119	9228	9337	9446	9556	9665	9774	
8	9883	9992									109
			0101	0210	0319	0428	0537	0646	0755	0864	
400	600973	1082	1191	1299	1408	1517	1625	1734	1843	1951	
	2060	2169	2277	2386	2494	2603	2711	2819	2928	3036	
1	3144	3253	3361	3469	3577	3686	3794	3902	4010	4118	108
2	4226	4334	4442	4550	4658	4766	4874	4982	5089	5197	
3	5305	5413	5521	5628	5736	5844	5951	6059	6166	6274	
4	6381	6489	6596	6704	6811	6919	7026	7133	7241	7348	
5	7455	7562	7669	7777	7884	7991	8098	8205	8312	8419	107
6	8526	8633	8740	8847	8954	9061	9167	9274	9381	9488	
7	9594	9701	9808	9914							
					0021	0128	0234	0341	0447	0554	
8	610660	0767	0873	0979	1086	1192	1298	1405	1511	1617	
9	1723	1829	1936	2042	2148	2254	2360	2466	2572	2678	106
410	2784	2890	2996	3102	3207	3313	3419	3525	3630	3736	
1	3842	3947	4053	4159	4264	4370	4475	4581	4686	4792	
2	4897	5003	5108	5213	5319	5424	5529	5634	5740	5845	
3	5950	6055	6160	6265	6370	6476	6581	6686	6790	6895	105
4	7000	7105	7210	7315	7420	7525	7629	7734	7839	7943	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
118	11.8	23.6	35.4	47.2	59.0	70.8	82.6	94.4	106.2
117	11.7	23.4	35.1	46.8	58.5	70.2	81.9	93.6	105.3
116	11.6	23.2	34.8	46.4	58.0	69.6	81.2	92.8	104.4
115	11.5	23.0	34.5	46.0	57.5	69.0	80.5	92.0	103.5
114	11.4	22.8	34.2	45.6	57.0	68.4	79.8	91.2	102.6
113	11.3	22.6	33.9	45.2	56.5	67.8	79.1	90.4	101.7
112	11.2	22.4	33.6	44.8	56.0	67.2	78.4	89.6	100.8
111	11.1	22.2	33.3	44.4	55.5	66.6	77.7	88.8	99.9
110	11.0	22.0	33.0	44.0	55.0	66.0	77.0	88.0	99.0
109	10.9	21.8	32.7	43.6	54.5	65.4	76.3	87.2	98.1
108	10.8	21.6	32.4	43.2	54.0	64.8	75.6	86.4	97.2
107	10.7	21.4	32.1	42.8	53.5	64.2	74.9	85.6	96.3
106	10.6	21.2	31.8	42.4	53.0	63.6	74.2	84.8	95.4
105	10.5	21.0	31.5	42.0	52.5	63.0	73.5	84.0	94.5
104	10.4	20.8	31.2	41.6	52.0	62.4	72.8	83.2	93.6

No. 415 L. 618.]

[No. 459 L. 662]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
415	618048	8153	8257	8362	8466	8571	8676	8780	8884	8989	105
6	9093	9198	9302	9406	9511	9615	9719	9824	9928		
7	620136	0240	0344	0448	0552	0656	0760	0864	0968	0032	104
8	1176	1280	1384	1488	1592	1695	1799	1903	2007	2110	
9	2214	2318	2421	2525	2628	2732	2835	2939	3042	3146	
420	3249	3353	3456	3559	3663	3766	3869	3973	4076	4179	
1	4282	4385	4488	4591	4695	4798	4901	5004	5107	5210	103
2	5312	5415	5518	5621	5724	5827	5929	6032	6135	6238	
3	6340	6443	6546	6648	6751	6853	6956	7058	7161	7263	
4	7366	7468	7571	7673	7775	7878	7980	8082	8185	8287	
5	8389	8491	8593	8695	8797	8900	9002	9104	9206	9308	102
6	9410	9512	9613	9715	9817	9919					
7	630428	0530	0631	0733	0835	0936	1038	1139	1241	1342	
8	1444	1545	1647	1748	1849	1951	2052	2153	2255	2356	
9	2457	2559	2660	2761	2862	2963	3064	3165	3266	3367	
430	3468	3569	3670	3771	3872	3973	4074	4175	4276	4376	101
1	4477	4578	4679	4779	4880	4981	5081	5182	5283	5383	
2	5484	5584	5685	5785	5886	5986	6087	6187	6287	6388	
3	6488	6588	6688	6789	6889	6989	7089	7189	7290	7390	
4	7490	7590	7690	7790	7890	7990	8090	8190	8290	8389	100
5	8489	8589	8689	8789	8888	8988	9088	9188	9287	9387	
6	9486	9586	9686	9785	9885	9984					
7	640481	0581	0680	0779	0879	0978	1077	1177	1276	1375	
8	1474	1573	1672	1771	1871	1970	2069	2168	2267	2366	
9	2465	2563	2662	2761	2860	2959	3058	3156	3255	3354	99
440	3453	3551	3650	3749	3847	3946	4044	4143	4242	4340	
1	4439	4537	4636	4734	4832	4931	5029	5127	5226	5324	
2	5422	5521	5619	5717	5815	5913	6011	6110	6208	6306	
3	6404	6502	6600	6698	6796	6894	6992	7089	7187	7285	98
4	7383	7481	7579	7676	7774	7872	7969	8067	8165	8262	
5	8360	8458	8555	8653	8750	8848	8945	9043	9140	9237	
6	9335	9432	9530	9627	9724	9821	9919				
7	650308	0405	0502	0599	0696	0793	0890	0987	1084	1181	
8	1278	1375	1472	1569	1666	1762	1859	1956	2053	2150	97
9	2246	2343	2440	2536	2633	2730	2826	2923	3019	3116	
450	3213	3309	3405	3502	3598	3695	3791	3888	3984	4080	
1	4177	4273	4369	4465	4562	4658	4754	4850	4946	5042	
2	5138	5235	5331	5427	5523	5619	5715	5810	5906	6002	96
3	6098	6194	6290	6386	6482	6577	6673	6769	6864	6960	
4	7056	7152	7247	7343	7438	7534	7629	7725	7820	7916	
5	8011	8107	8202	8298	8393	8488	8584	8679	8774	8870	
6	8965	9060	9155	9250	9346	9441	9536	9631	9726	9821	
7	9916										
8	660865	0011	0106	0201	0296	0391	0486	0581	0676	0771	95
9	1813	0960	1055	1150	1245	1339	1434	1529	1623	1718	
		1907	2002	2096	2191	2286	2380	2475	2569	2663	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
105	10.5	21.0	31.5	42.0	52.5	63.0	73.5	84.0	94.5
104	10.4	20.8	31.2	41.6	52.0	62.4	72.8	83.2	93.6
103	10.3	20.6	30.9	41.2	51.5	61.8	72.1	82.4	92.7
102	10.2	20.4	30.6	40.8	51.0	61.2	71.4	81.6	91.8
101	10.1	20.2	30.3	40.4	50.5	60.6	70.7	80.8	90.9
100	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
99	9.9	19.8	29.7	39.6	49.5	59.4	69.3	79.2	89.1

No. 460 L. 662.]

[No. 499 L. 698.]

N	0	1	2	3	4	5	6	7	8	9	Diff.
460	662758	2852	2947	3041	3135	3230	3324	3418	3512	3607	
1	3701	3795	3889	3983	4078	4172	4266	4360	4454	4548	
2	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	94
3	5581	5675	5769	5862	5956	6050	6143	6237	6331	6424	
4	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	
5	7453	7546	7640	7733	7826	7920	8013	8106	8199	8293	
6	8386	8479	8572	8665	8759	8852	8945	9038	9131	9224	
7	9317	9410	9503	9596	9689	9782	9875	9967			
8	670246	0339	0431	0524	0617	0710	0802	0895	0988	1080	93
9	1173	1265	1358	1451	1543	1636	1728	1821	1913	2005	
470	2098	2190	2283	2375	2467	2560	2652	2744	2836	2929	
1	3021	3113	3205	3297	3390	3482	3574	3666	3758	3850	
2	3942	4034	4126	4218	4310	4402	4494	4586	4677	4769	92
3	4861	4953	5045	5137	5228	5320	5412	5503	5595	5687	
4	5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	
5	6694	6785	6876	6968	7059	7151	7242	7333	7424	7516	
6	7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	
7	8518	8609	8700	8791	8882	8973	9064	9155	9246	9337	91
8	9428	9519	9610	9700	9791	9882	9973				
9	680336	0426	0517	0607	0698	0789	0879	0970	1060	1151	
480	1241	1332	1422	1513	1603	1693	1784	1874	1964	2055	
1	2145	2235	2326	2416	2506	2596	2686	2777	2867	2957	
2	3047	3137	3227	3317	3407	3497	3587	3677	3767	3857	90
3	3947	4037	4127	4217	4307	4396	4486	4576	4666	4756	
4	4845	4935	5025	5114	5204	5294	5383	5473	5563	5652	
5	5742	5831	5921	6010	6100	6189	6279	6368	6458	6547	
6	6636	6726	6815	6904	6994	7083	7172	7261	7351	7440	
7	7529	7618	7707	7796	7886	7975	8064	8153	8242	8331	89
8	8420	8509	8598	8687	8776	8865	8953	9042	9131	9220	
9	9309	9398	9486	9575	9664	9753	9841	9930			
490	690196	0285	0373	0462	0550	0639	0728	0816	0905	0993	
1	1081	1170	1258	1347	1435	1524	1612	1700	1789	1877	
2	1965	2053	2142	2230	2318	2406	2494	2583	2671	2759	
3	2847	2935	3023	3111	3199	3287	3375	3463	3551	3639	88
4	3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	
5	4605	4693	4781	4868	4956	5044	5131	5219	5307	5394	
6	5482	5569	5657	5744	5832	5919	6007	6094	6182	6269	
7	6356	6444	6531	6618	6706	6793	6880	6968	7055	7142	
8	7229	7317	7404	7491	7578	7665	7752	7839	7926	8014	
9	8100	8188	8275	8362	8449	8535	8622	8709	8796	8883	87

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
98	9.8	19.6	29.4	39.2	49.0	58.8	68.6	78.4	88.2
97	9.7	19.4	29.1	38.8	48.5	58.2	67.9	77.6	87.3
96	9.6	19.2	28.8	38.4	48.0	57.6	67.2	76.8	86.4
95	9.5	19.0	28.5	38.0	47.5	57.0	66.5	76.0	85.5
94	9.4	18.8	28.2	37.6	47.0	56.4	65.8	75.2	84.6
93	9.3	18.6	27.9	37.2	46.5	55.8	65.1	74.4	83.7
92	9.2	18.4	27.6	36.8	46.0	55.2	64.4	73.6	82.8
91	9.1	18.2	27.3	36.4	45.5	54.6	63.7	72.8	81.9
90	9.0	18.0	27.0	36.0	45.0	54.0	63.0	72.0	81.0
89	8.9	17.8	26.7	35.6	44.5	53.4	62.3	71.2	80.1
88	8.8	17.6	26.4	35.2	44.0	52.8	61.6	70.4	79.2
87	8.7	17.4	26.1	34.8	43.5	52.2	60.9	69.6	78.3
86	8.6	17.2	25.8	34.4	43.0	51.6	60.2	68.8	77.4

No. 500 L. 698.]

[No. 544 L. 786.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
500	698970	9057	9144	9231	9318	9404	9491	9578	9664	9751	
1	9838	9924									
2	700704	0790	0011	0098	0184	0271	0358	0444	0531	0617	
3	1568	1654	0877	0963	1050	1136	1222	1309	1395	1482	
4	2431	2517	1741	1827	1913	1999	2086	2172	2258	2344	
5	3291	3377	2603	2689	2775	2861	2947	3033	3119	3205	
6	4151	4236	3463	3549	3635	3721	3807	3893	3979	4065	86
7	5008	5094	4322	4408	4494	4579	4665	4751	4837	4922	
8	5864	5949	5179	5265	5350	5436	5522	5607	5693	5778	
9	6718	6803	6035	6120	6206	6291	6376	6462	6547	6632	
			6888	6974	7059	7144	7229	7315	7400	7485	
510	7570	7655	7740	7826	7911	7996	8081	8166	8251	8336	
1	8421	8506	8591	8676	8761	8846	8931	9015	9100	9185	85
2	9270	9355	9440	9524	9609	9694	9779	9863	9948		
										0033	
3	710117	0202	0287	0371	0456	0540	0625	0710	0794	0879	
4	0963	1048	1132	1217	1301	1385	1470	1554	1639	1723	
5	1807	1892	1976	2060	2144	2229	2313	2397	2481	2566	
6	2650	2734	2818	2902	2986	3070	3154	3238	3323	3407	
7	3491	3575	3659	3742	3826	3910	3994	4078	4162	4246	84
8	4330	4414	4497	4581	4665	4749	4833	4916	5000	5084	
9	5167	5251	5335	5418	5502	5586	5669	5753	5836	5920	
520	6008	6087	6170	6254	6337	6421	6504	6588	6671	6754	
1	6838	6921	7004	7088	7171	7254	7338	7421	7504	7587	
2	7671	7754	7837	7920	8003	8086	8169	8253	8336	8419	
3	8502	8585	8668	8751	8834	8917	9000	9083	9165	9248	83
4	9331	9414	9497	9580	9663	9745	9828	9911	9994		
										0077	
5	720159	0242	0325	0407	0490	0573	0655	0738	0821	0903	
6	0986	1068	1151	1233	1316	1398	1481	1563	1646	1728	
7	1811	1893	1975	2058	2140	2222	2305	2387	2469	2552	
8	2634	2716	2798	2881	2963	3045	3127	3209	3291	3374	
9	3456	3538	3620	3702	3784	3866	3948	4030	4112	4194	82
530	4276	4358	4440	4522	4604	4685	4767	4849	4931	5013	
1	5095	5176	5258	5340	5422	5503	5585	5667	5748	5830	
2	5912	5993	6075	6156	6238	6320	6401	6483	6564	6646	
3	6727	6809	6890	6972	7053	7134	7216	7297	7379	7460	
4	7541	7623	7704	7785	7866	7948	8029	8110	8191	8273	
5	8354	8435	8516	8597	8678	8759	8841	8922	9003	9084	
6	9165	9246	9327	9408	9489	9570	9651	9732	9813	9893	81
7	9974										
		0055	0136	0217	0298	0379	0459	0540	0621	0702	
8	730782	0863	0944	1024	1105	1186	1266	1347	1428	1508	
9	1589	1669	1750	1830	1911	1991	2072	2152	2233	2313	
540	2394	2474	2555	2635	2715	2796	2876	2956	3037	3117	
1	3197	3278	3358	3438	3518	3598	3679	3759	3839	3919	
2	3999	4079	4160	4240	4320	4400	4480	4560	4640	4720	
3	4800	4880	4960	5040	5120	5200	5279	5359	5439	5519	80
4	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
87	8.7	17.4	26.1	34.8	43.5	52.2	60.9	69.6	78.3
86	8.6	17.2	25.8	34.4	43.0	51.6	60.2	68.8	77.4
85	8.5	17.0	25.5	34.0	42.5	51.0	59.5	68.0	76.5
84	8.4	16.8	25.2	33.6	42.0	50.4	58.8	67.2	75.6

No. 545 L. 736.]

[No. 584 L. 767.]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
545	736397	6476	6556	6635	6715	6795	6874	6954	7034	7113	
6	7193	7272	7352	7431	7511	7590	7670	7749	7829	7908	
7	7987	8067	8146	8225	8305	8384	8463	8543	8622	8701	
8	8781	8860	8939	9018	9097	9177	9256	9335	9414	9493	
9	9572	9651	9731	9810	9889	9968					
							0047	0126	0205	0284	79
550	740363	0442	0521	0600	0678	0757	0836	0915	0994	1073	
1	1152	1230	1309	1388	1467	1546	1624	1703	1782	1860	
2	1939	2018	2096	2175	2254	2332	2411	2489	2568	2647	
3	2725	2804	2882	2961	3039	3118	3196	3275	3353	3431	
4	3510	3588	3667	3745	3823	3902	3980	4058	4136	4215	
5	4293	4371	4449	4528	4606	4684	4762	4840	4919	4997	
6	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
7	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	
8	6634	6712	6790	6868	6945	7023	7101	7179	7256	7334	
9	7412	7489	7567	7645	7722	7800	7878	7955	8033	8110	
560	8188	8266	8343	8421	8498	8576	8653	8731	8808	8885	
1	8963	9040	9118	9195	9272	9350	9427	9504	9582	9659	
2	9736	9814	9891	9968							
					0045	0123	0200	0277	0354	0431	
3	750508	0586	0663	0740	0817	0894	0971	1048	1125	1202	
4	1279	1356	1433	1510	1587	1664	1741	1818	1895	1972	77
5	2048	2125	2202	2279	2356	2433	2509	2586	2663	2740	
6	2816	2893	2970	3047	3123	3200	3277	3353	3430	3506	
7	3583	3660	3736	3813	3889	3966	4042	4119	4195	4272	
8	4348	4425	4501	4578	4654	4730	4807	4883	4960	5036	
9	5112	5189	5265	5341	5417	5494	5570	5646	5722	5799	
570	5875	5951	6027	6103	6180	6256	6332	6408	6484	6560	
1	6636	6712	6788	6864	6940	7016	7092	7168	7244	7320	76
2	7396	7472	7548	7624	7700	7775	7851	7927	8003	8079	
3	8155	8230	8306	8382	8458	8533	8609	8685	8761	8836	
4	8912	8988	9063	9139	9214	9290	9366	9441	9517	9592	
5	9668	9743	9819	9894	9970						
						0045	0121	0196	0272	0347	
6	760422	0498	0573	0649	0724	0799	0875	0950	1025	1101	
7	1176	1251	1326	1402	1477	1552	1627	1702	1778	1853	
8	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604	
9	2679	2754	2829	2904	2978	3053	3128	3203	3278	3353	75
580	3428	3503	3578	3653	3727	3802	3877	3952	4027	4101	
1	4176	4251	4326	4400	4475	4550	4624	4699	4774	4848	
2	4923	4998	5072	5147	5221	5296	5370	5445	5520	5594	
3	5669	5743	5818	5892	5966	6041	6115	6190	6264	6338	
4	6413	6487	6562	6636	6710	6785	6859	6933	7007	7082	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
83	8.3	16.6	24.9	33.2	41.5	49.8	58.1	66.4	74.7
82	8.2	16.4	24.6	32.8	41.0	49.2	57.4	65.6	73.8
81	8.1	16.2	24.3	32.4	40.5	48.6	56.7	64.8	72.9
80	8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0
79	7.9	15.8	23.7	31.6	39.5	47.4	55.3	63.2	71.1
78	7.8	15.6	23.4	31.2	39.0	46.8	54.6	62.4	70.2
77	7.7	15.4	23.1	30.8	38.5	46.2	53.9	61.6	69.3
76	7.6	15.2	22.8	30.4	38.0	45.6	53.2	60.8	68.4
75	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5
74	7.4	14.8	22.2	29.6	37.0	44.4	51.8	59.2	66.6

No. 585 L. 767.]

[No. 629 L. 799.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
585	767156	7230	7304	7379	7453	7527	7601	7675	7749	7823	74
6	7898	7972	8046	8120	8194	8268	8342	8416	8490	8564	
7	8638	8712	8786	8860	8934	9008	9082	9156	9230	9303	
8	9377	9451	9525	9599	9673	9746	9820	9894	9968	0042	
9	770115	0189	0263	0336	0410	0484	0557	0631	0705	0778	73
590	0852	0926	0999	1073	1146	1220	1293	1367	1440	1514	
1	1587	1631	1734	1808	1881	1955	2028	2102	2175	2248	
2	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981	
3	3055	3128	3201	3274	3348	3421	3494	3567	3640	3713	
4	3786	3860	3933	4006	4079	4152	4225	4298	4371	4444	
5	4517	4590	4663	4736	4809	4882	4955	5028	5100	5173	
6	5246	5319	5392	5465	5538	5610	5683	5756	5829	5902	
7	5974	6047	6120	6193	6265	6338	6411	6483	6556	6629	
8	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354	
9	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079	
600	8151	8224	8296	8368	8441	8513	8585	8658	8730	8802	72
1	8874	8947	9019	9091	9163	9236	9308	9380	9452	9524	
2	9596	9669	9741	9813	9885	9957	0029	0101	0173	0245	
3	780317	0389	0461	0533	0605	0677	0749	0821	0893	0965	
4	1037	1109	1181	1253	1324	1396	1468	1540	1612	1684	
5	1755	1827	1899	1971	2042	2114	2186	2258	2329	2401	
6	2473	2544	2616	2688	2759	2831	2902	2974	3046	3117	
7	3189	3260	3332	3403	3475	3546	3618	3689	3761	3832	
8	3904	3975	4046	4118	4189	4261	4332	4403	4475	4546	
9	4617	4689	4760	4831	4902	4974	5045	5116	5187	5259	
610	5330	5401	5472	5543	5615	5686	5757	5828	5899	5970	71
1	6041	6112	6183	6254	6325	6396	6467	6538	6609	6680	
2	6751	6822	6893	6964	7035	7106	7177	7248	7319	7390	
3	7460	7531	7602	7673	7744	7815	7885	7956	8027	8098	
4	8168	8239	8310	8381	8451	8522	8593	8663	8734	8804	
5	8875	8946	9016	9087	9157	9228	9299	9369	9440	9510	
6	9581	9651	9722	9792	9863	9933	0004	0074	0144	0215	
7	790285	0356	0426	0496	0567	0637	0707	0778	0848	0918	
8	0988	1059	1129	1199	1269	1340	1410	1480	1550	1620	
9	1691	1761	1831	1901	1971	2041	2111	2181	2252	2322	
620	2392	2462	2532	2602	2672	2742	2812	2882	2952	3022	70
1	3092	3162	3231	3301	3371	3441	3511	3581	3651	3721	
2	3790	3860	3930	4000	4070	4139	4209	4279	4349	4418	
3	4488	4558	4627	4697	4767	4836	4906	4976	5045	5115	
4	5185	5254	5324	5393	5463	5532	5602	5672	5741	5811	
5	5880	5949	6019	6088	6158	6227	6297	6366	6436	6505	
6	6574	6644	6713	6782	6852	6921	6990	7060	7129	7198	
7	7268	7337	7406	7475	7545	7614	7683	7752	7821	7890	
8	7960	8029	8098	8167	8236	8305	8374	8443	8513	8582	
9	8651	8720	8789	8858	8927	8996	9065	9134	9203	9272	69

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
75	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5
74	7.4	14.8	22.2	29.6	37.0	44.4	51.8	59.2	66.6
73	7.3	14.6	21.9	29.2	36.5	43.8	51.1	58.4	65.7
72	7.2	14.4	21.6	28.8	36.0	43.2	50.4	57.6	64.8
71	7.1	14.2	21.3	28.4	35.5	42.6	49.7	56.8	63.9
70	7.0	14.0	21.0	28.0	35.0	42.0	49.0	56.0	63.0
69	6.9	13.8	20.7	27.6	34.5	41.4	48.3	55.2	62.1

No. 630 L. 799.]

[No. 674 L. 829.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
630	799341	9409	9478	9547	9616	9685	9754	9823	9892	9961	
1	800029	0098	0167	0236	0305	0373	0442	0511	0580	0648	
2	0717	0786	0854	0923	0992	1061	1129	1198	1266	1335	
3	1404	1472	1541	1609	1678	1747	1815	1884	1952	2021	
4	2089	2158	2226	2295	2363	2432	2500	2568	2637	2705	
5	2774	2842	2910	2979	3047	3116	3184	3252	3321	3389	
6	3457	3525	3594	3662	3730	3798	3867	3935	4003	4071	
7	4139	4208	4276	4344	4412	4480	4548	4616	4685	4753	
8	4821	4889	4957	5025	5093	5161	5229	5297	5365	5433	68
9	5501	5569	5637	5705	5773	5841	5908	5976	6044	6112	
640	806180	6248	6316	6384	6451	6519	6587	6655	6723	6790	
1	6858	6926	6994	7061	7129	7197	7264	7332	7400	7467	
2	7535	7603	7670	7738	7806	7873	7941	8008	8076	8143	
3	8211	8279	8346	8414	8481	8549	8616	8684	8751	8818	
4	8886	8953	9021	9088	9156	9223	9290	9358	9425	9492	
5	9560	9627	9694	9762	9829	9896	9964				
6	810233	0300	0367	0434	0501	0569	0636	0703	0770	0837	
7	0904	0971	1039	1106	1173	1240	1307	1374	1441	1508	67
8	1575	1642	1709	1776	1843	1910	1977	2044	2111	2178	
9	2245	2312	2379	2445	2512	2579	2646	2713	2780	2847	
650	2913	2980	3047	3114	3181	3247	3314	3381	3448	3514	
1	3581	3648	3714	3781	3848	3914	3981	4048	4114	4181	
2	4248	4314	4381	4447	4514	4581	4647	4714	4780	4847	
3	4913	4980	5046	5113	5179	5246	5312	5378	5445	5511	
4	5578	5644	5711	5777	5843	5910	5976	6042	6109	6175	
5	6241	6308	6374	6440	6506	6573	6639	6705	6771	6838	
6	6904	6970	7036	7102	7169	7235	7301	7367	7433	7499	
7	7565	7631	7698	7764	7830	7896	7962	8028	8094	8160	
8	8226	8292	8358	8424	8490	8556	8622	8688	8754	8820	
9	8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	66
660	9544	9610	9676	9741	9807	9873	9939				
1	820201	0267	0333	0399	0464	0530	0595	0661	0727	0792	
2	0858	0924	0989	1055	1120	1186	1251	1317	1382	1448	
3	1514	1579	1645	1710	1775	1841	1906	1972	2037	2103	
4	2168	2233	2299	2364	2430	2495	2560	2626	2691	2756	
5	2822	2887	2952	3018	3083	3148	3213	3279	3344	3409	
6	3474	3539	3605	3670	3735	3800	3865	3930	3996	4061	
7	4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	
8	4776	4841	4906	4971	5036	5101	5166	5231	5296	5361	65
9	5426	5491	5556	5621	5686	5751	5815	5880	5945	6010	
670	6075	6140	6204	6269	6334	6399	6464	6528	6593	6658	
1	6723	6787	6852	6917	6981	7046	7111	7175	7240	7305	
2	7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	
3	8015	8080	8144	8209	8273	8338	8402	8467	8531	8595	
4	8660	8724	8789	8853	8918	8982	9046	9111	9175	9239	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
68	6.8	13.6	20.4	27.2	34.0	40.8	47.6	54.4	61.2
67	6.7	13.4	20.1	26.8	33.5	40.2	46.9	53.6	60.3
66	6.6	13.2	19.8	26.4	33.0	39.6	46.2	52.8	59.4
65	6.5	13.0	19.5	26.0	32.5	39.0	45.5	52.0	58.5
64	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6

100 TABLE XXIV.—LOGARITHMS OF NUMBERS

No. 675 L. 829.]

No. 719 L. 857.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
675	829304	9368	9432	9497	9561	9625	9690	9754	9818	9882	
6	9947										
7	830589	0011	0075	0139	0204	0268	0332	0396	0460	0525	
8	1230	0653	0717	0781	0845	0909	0973	1037	1102	1166	
9	1870	1294	1358	1422	1486	1550	1614	1678	1742	1806	64
		1934	1998	2062	2126	2189	2253	2317	2381	2445	
680	2509	2573	2637	2700	2764	2828	2892	2956	3020	3083	
1	3147	3211	3275	3338	3402	3466	3530	3593	3657	3721	
2	3784	3848	3912	3975	4039	4103	4166	4230	4294	4357	
3	4421	4484	4548	4611	4675	4739	4802	4866	4929	4993	
4	5056	5120	5183	5247	5310	5373	5437	5500	5564	5627	
5	5691	5754	5817	5881	5944	6007	6071	6134	6197	6261	
6	6324	6387	6451	6514	6577	6641	6704	6767	6830	6894	
7	6957	7020	7083	7146	7210	7273	7336	7399	7462	7525	
8	7588	7652	7715	7778	7841	7904	7967	8030	8093	8156	
9	8219	8282	8345	8408	8471	8534	8597	8660	8723	8786	63
690	8849	8912	8975	9038	9101	9164	9227	9289	9352	9415	
1	9478	9541	9604	9667	9729	9792	9855	9918	9981		
2	840106	0169	0232	0294	0357	0420	0482	0545	0608	0043	
3	0733	0796	0859	0921	0984	1046	1109	1172	1234	0671	
4	1359	1422	1485	1547	1610	1672	1735	1797	1860	1297	
5	1985	2047	2110	2172	2235	2297	2360	2422	2484	1922	
6	2609	2672	2734	2796	2859	2921	2983	3046	3108	2547	
7	3233	3295	3357	3420	3482	3544	3606	3669	3731	3170	
8	3855	3918	3980	4042	4104	4166	4229	4291	4353	3793	
9	4477	4539	4601	4664	4726	4788	4850	4912	4974	4415	
700	5098	5160	5222	5284	5346	5408	5470	5532	5594	5036	
1	5718	5780	5842	5904	5966	6028	6090	6151	6213	5656	
2	6337	6399	6461	6523	6585	6646	6708	6770	6832	6275	62
3	6955	7017	7079	7141	7202	7264	7326	7388	7449	6894	
4	7573	7634	7696	7758	7819	7881	7943	8004	8066	7511	
5	8189	8251	8312	8374	8435	8497	8559	8620	8682	8128	
6	8805	8866	8928	8989	9051	9112	9174	9235	9297	8743	
7	9419	9481	9542	9604	9665	9726	9788	9849	9911	9358	
8	850033	0095	0156	0217	0279	0340	0401	0462	0524	9972	
9	0646	0707	0769	0830	0891	0952	1014	1075	1136	0585	
710	1258	1320	1381	1442	1503	1564	1625	1686	1747	1197	
1	1870	1931	1992	2053	2114	2175	2236	2297	2358	1809	
2	2480	2541	2602	2663	2724	2785	2846	2907	2968	2419	
3	3090	3150	3211	3272	3333	3394	3455	3516	3577	3029	61
4	3698	3759	3820	3881	3941	4002	4063	4124	4185	3637	
5	4306	4367	4428	4488	4549	4610	4670	4731	4792	4245	
6	4913	4974	5034	5095	5156	5216	5277	5337	5398	4852	
7	5519	5580	5640	5701	5761	5822	5882	5943	6003	5459	
8	6124	6185	6245	6306	6366	6427	6487	6548	6608	6064	
9	6729	6789	6850	6910	6970	7031	7091	7152	7212	6668	
										7272	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
65	6.5	13.0	19.5	26.0	32.5	39.0	45.5	52.0	58.5
64	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6
63	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7
62	6.2	12.4	18.6	24.8	31.0	37.2	43.4	49.6	55.8
61	6.1	12.2	18.3	24.4	30.5	36.6	42.7	48.8	54.9
60	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0

No. 720 L. 857.]

[No. 764 L. 883.]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
720	857332	7393	7453	7513	7574	7634	7694	7755	7815	7875	60
1	7935	7995	8056	8116	8176	8236	8297	8357	8417	8477	
2	8537	8597	8657	8718	8778	8838	8898	8958	9018	9078	
3	9138	9198	9258	9318	9379	9439	9499	9559	9619	9679	
4	9739	9799	9859	9918	9978						
5	860338	0398	0458	0518	0578	0038	0098	0158	0218	0278	
6	0937	0996	1056	1116	1176	0637	0697	0757	0817	0877	
7	1534	1594	1654	1714	1773	1236	1295	1355	1415	1475	
8	2131	2191	2251	2310	2370	1833	1893	1952	2012	2072	
9	2728	2787	2847	2906	2966	2430	2489	2549	2608	2668	
730	3323	3382	3442	3501	3561	3620	3680	3739	3799	3858	69
1	3917	3977	4036	4096	4155	4214	4274	4333	4392	4452	
2	4511	4570	4630	4689	4748	4808	4867	4926	4985	5045	
3	5104	5163	5222	5282	5341	5400	5459	5519	5578	5637	
4	5696	5755	5814	5874	5933	5992	6051	6110	6169	6228	
5	6287	6346	6405	6465	6524	6583	6642	6701	6760	6819	
6	6878	6937	6996	7055	7114	7173	7232	7291	7350	7409	
7	7467	7526	7585	7644	7703	7762	7821	7880	7939	7998	
8	8056	8115	8174	8233	8292	8350	8409	8468	8527	8586	
9	8644	8703	8762	8821	8879	8938	8997	9056	9114	9173	
740	9232	9290	9349	9408	9466	9525	9584	9642	9701	9760	58
1	9818	9877	9935	9994							
2	870404	0462	0521	0579	0638	0111	0170	0228	0287	0345	
3	0989	1047	1106	1164	1223	0696	0755	0813	0872	0930	
4	1573	1631	1690	1748	1806	1281	1339	1398	1456	1515	
5	2156	2215	2273	2331	2389	1865	1923	1981	2040	2098	
6	2739	2797	2855	2913	2972	2448	2506	2564	2622	2681	
7	3321	3379	3437	3495	3553	3030	3088	3146	3204	3262	
8	3902	3960	4018	4076	4134	3611	3669	3727	3785	3844	
9	4482	4540	4598	4656	4714	4192	4250	4308	4366	4424	
750	5061	5119	5177	5235	5293	4772	4830	4888	4945	5003	57
1	5640	5698	5756	5813	5871	5351	5409	5466	5524	5582	
2	6218	6276	6333	6391	6449	5929	5987	6045	6102	6160	
3	6795	6853	6910	6968	7026	6507	6564	6622	6680	6737	
4	7371	7429	7487	7544	7602	7083	7141	7199	7256	7314	
5	7947	8004	8062	8119	8177	7659	7717	7774	7832	7889	
6	8522	8579	8637	8694	8752	8234	8292	8349	8407	8464	
7	9096	9153	9211	9268	9325	8809	8866	8924	8981	9039	
8	9669	9726	9784	9841	9898	9383	9440	9497	9555	9612	
9	880242	0299	0356	0413	0471	0528	0585	0642	0699	0756	
760	0814	0871	0928	0985	1042	1099	1156	1213	1271	1328	57
1	1385	1442	1499	1556	1613	1670	1727	1784	1841	1898	
2	1955	2012	2069	2126	2183	2240	2297	2354	2411	2468	
3	2525	2581	2638	2695	2752	2809	2866	2923	2980	3037	
4	3093	3150	3207	3264	3321	3377	3434	3491	3548	3605	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
59	5.9	11.8	17.7	23.6	29.5	35.4	41.3	47.2	53.1
58	5.8	11.6	17.4	23.2	29.0	34.8	40.6	46.4	52.2
57	5.7	11.4	17.1	22.8	28.5	34.2	39.9	45.6	51.3
56	5.6	11.2	16.8	22.4	28.0	33.6	39.2	44.8	50.4

102 TABLE XXIV.—LOGARITHMS OF NUMBERS

No. 765 L. 883.]

[No. 809 L. 908.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
765	883661	3718	3775	3832	3888	3945	4002	4059	4115	4172	
6	4229	4285	4342	4399	4455	4512	4569	4625	4682	4739	
7	4795	4852	4909	4965	5022	5078	5135	5192	5248	5305	
8	5361	5418	5474	5531	5587	5644	5700	5757	5813	5870	
9	5926	5983	6039	6096	6152	6209	6265	6321	6378	6434	
770	6491	6547	6604	6660	6716	6773	6829	6885	6942	6998	
1	7054	7111	7167	7223	7280	7336	7392	7449	7505	7561	
2	7617	7674	7730	7786	7842	7898	7955	8011	8067	8123	
3	8179	8236	8292	8348	8404	8460	8516	8573	8629	8685	
4	8741	8797	8853	8909	8965	9021	9077	9134	9190	9246	
5	9302	9358	9414	9470	9526	9582	9638	9694	9750	9806	56
6	9862	9918	9974								
				0030	0086	0141	0197	0253	0309	0365	
7	890421	0477	0533	0589	0645	0700	0756	0812	0868	0924	
8	0980	1035	1091	1147	1203	1259	1314	1370	1426	1482	
9	1537	1593	1649	1705	1760	1816	1872	1928	1983	2039	
780	2095	2150	2206	2262	2317	2373	2429	2484	2540	2595	
1	2651	2707	2762	2818	2873	2929	2985	3040	3096	3151	
2	3207	3262	3318	3373	3429	3484	3540	3595	3651	3706	
3	3762	3817	3873	3928	3984	4039	4094	4150	4205	4261	
4	4316	4371	4427	4482	4538	4593	4648	4704	4759	4814	
5	4870	4925	4980	5036	5091	5146	5201	5257	5312	5367	
6	5423	5478	5533	5588	5644	5699	5754	5809	5864	5920	
7	5975	6030	6085	6140	6195	6251	6306	6361	6416	6471	
8	6526	6581	6636	6692	6747	6802	6857	6912	6967	7022	
9	7077	7132	7187	7242	7297	7352	7407	7462	7517	7572	55
790	7627	7682	7737	7792	7847	7902	7957	8012	8067	8122	
1	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	
2	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	
3	9273	9328	9383	9437	9492	9547	9602	9656	9711	9766	
4	9821	9875	9930	9985							
				0039	0094	0149	0203	0258	0312		
5	900367	0422	0476	0531	0586	0640	0695	0749	0804	0859	
6	0913	0968	1022	1077	1131	1186	1240	1295	1349	1404	
7	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	
8	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	
9	2547	2601	2655	2710	2764	2818	2873	2927	2981	3036	
800	3090	3144	3199	3253	3307	3361	3416	3470	3524	3578	
1	3633	3687	3741	3795	3849	3904	3958	4012	4066	4120	
2	4174	4229	4283	4337	4391	4445	4499	4553	4607	4661	
3	4716	4770	4824	4878	4932	4986	5040	5094	5148	5202	
4	5256	5310	5364	5418	5472	5526	5580	5634	5688	5742	54
5	5796	5850	5904	5958	6012	6066	6119	6173	6227	6281	
6	6335	6389	6443	6497	6551	6604	6658	6712	6766	6820	
7	6874	6927	6981	7035	7089	7143	7196	7250	7304	7358	
8	7411	7465	7519	7573	7626	7680	7734	7787	7841	7895	
9	7949	8002	8056	8110	8163	8217	8270	8324	8378	8431	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
57	5.7	11.4	17.1	22.8	28.5	34.2	39.9	45.6	51.3
56	5.6	11.2	16.8	22.4	28.0	33.6	39.2	44.8	50.4
55	5.5	11.0	16.5	22.0	27.5	33.0	38.5	44.0	49.5
54	5.4	10.8	16.2	21.6	27.0	32.4	37.8	43.2	48.6

No. 810 L. 908.]

[No. 854 L. 931.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
810	908485	8539	8592	8646	8699	8758	8807	8860	8914	8967	53
1	9021	9074	9128	9181	9235	9289	9342	9396	9449	9503	
2	9556	9610	9663	9716	9770	9823	9877	9930	9984	0037	
3	910091	0144	0197	0251	0304	0358	0411	0464	0518	0571	
4	0624	0678	0731	0784	0838	0891	0944	0998	1051	1104	
5	1158	1211	1264	1317	1371	1424	1477	1530	1584	1637	
6	1690	1743	1797	1850	1903	1956	2009	2063	2116	2169	
7	2222	2275	2328	2381	2435	2488	2541	2594	2647	2700	
8	2753	2806	2859	2913	2966	3019	3072	3125	3178	3231	
9	3284	3337	3390	3443	3496	3549	3602	3655	3708	3761	
820	3814	3867	3920	3973	4026	4079	4132	4184	4237	4290	52
1	4343	4396	4449	4502	4555	4608	4660	4713	4766	4819	
2	4872	4925	4977	5030	5083	5136	5189	5241	5294	5347	
3	5400	5453	5505	5558	5611	5664	5716	5769	5822	5875	
4	5927	5980	6033	6085	6138	6191	6243	6296	6349	6401	
5	6454	6507	6559	6612	6664	6717	6770	6822	6875	6927	
6	6980	7033	7085	7138	7190	7243	7295	7348	7400	7453	
7	7506	7558	7611	7663	7716	7768	7820	7873	7925	7978	
8	8030	8083	8135	8188	8240	8293	8345	8397	8450	8502	
9	8555	8607	8659	8712	8764	8816	8869	8921	8973	9026	
830	9078	9130	9183	9235	9287	9340	9392	9444	9496	9549	51
1	9601	9653	9706	9758	9810	9862	9914	9967	0019	0071	
2	920123	0176	0228	0280	0332	0384	0436	0489	0541	0593	
3	0645	0697	0749	0801	0853	0906	0958	1010	1062	1114	
4	1166	1218	1270	1322	1374	1426	1478	1530	1582	1634	
5	1686	1738	1790	1842	1894	1946	1998	2050	2102	2154	
6	2206	2258	2310	2362	2414	2466	2518	2570	2622	2674	
7	2725	2777	2829	2881	2933	2985	3037	3089	3140	3192	
8	3244	3296	3348	3399	3451	3503	3555	3607	3658	3710	
9	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	
840	4279	4331	4383	4434	4486	4538	4589	4641	4693	4744	51
1	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	
2	5312	5364	5415	5467	5518	5570	5621	5673	5725	5776	
3	5828	5879	5931	5982	6034	6085	6137	6188	6240	6291	
4	6342	6394	6445	6497	6548	6600	6651	6702	6754	6805	
5	6857	6908	6959	7011	7062	7114	7165	7216	7268	7319	
6	7370	7422	7473	7524	7575	7627	7678	7730	7781	7832	
7	7883	7935	7986	8037	8088	8140	8191	8242	8293	8345	
8	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	
9	8908	8959	9010	9061	9112	9163	9215	9266	9317	9368	
850	9419	9470	9521	9572	9623	9674	9725	9776	9827	9879	51
1	9930	9981	0032	0083	0134	0185	0236	0287	0338	0389	
2	930440	0491	0542	0592	0643	0694	0745	0796	0847	0898	
3	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	
4	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
53	5.3	10.6	15.9	21.2	26.5	31.8	37.1	42.4	47.7
52	5.2	10.4	15.6	20.8	26.0	31.2	36.4	41.6	46.8
51	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	45.9
50	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0

104 TABLE XXIV.—LOGARITHMS OF NUMBERS

No. 855 L. 931.]

[No. 899 L. 954.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
855	931966	2017	2068	2118	2169	2220	2271	2322	2372	2423	
6	2474	2524	2575	2626	2677	2727	2778	2829	2879	2930	
7	2981	3031	3082	3133	3183	3234	3285	3335	3386	3437	
8	3487	3538	3589	3639	3690	3740	3791	3841	3892	3943	
9	3993	4044	4094	4145	4195	4246	4296	4347	4397	4448	
860	4498	4549	4599	4650	4700	4751	4801	4852	4902	4953	
1	5003	5054	5104	5154	5205	5255	5306	5356	5406	5457	
2	5507	5558	5608	5658	5709	5759	5809	5860	5910	5960	
3	6011	6061	6111	6162	6212	6262	6313	6363	6413	6463	
4	6514	6564	6614	6665	6715	6765	6815	6865	6916	6966	
5	7016	7066	7116	7167	7217	7267	7317	7367	7418	7468	
6	7518	7568	7618	7668	7718	7769	7819	7869	7919	7969	
7	8019	8069	8119	8169	8219	8269	8320	8370	8420	8470	50
8	8520	8570	8620	8670	8720	8770	8820	8870	8920	8970	
9	9020	9070	9120	9170	9220	9270	9320	9369	9419	9469	
870	9519	9569	9619	9669	9719	9769	9819	9869	9918	9968	
1	940018	0068	0118	0168	0218	0267	0317	0367	0417	0467	
2	0516	0566	0616	0666	0716	0765	0815	0865	0915	0964	
3	1014	1064	1114	1163	1213	1263	1313	1362	1412	1462	
4	1511	1561	1611	1660	1710	1760	1809	1859	1909	1958	
5	2008	2058	2107	2157	2207	2256	2306	2355	2405	2455	
6	2504	2554	2603	2653	2702	2752	2801	2851	2901	2950	
7	3000	3049	3099	3148	3198	3247	3297	3346	3396	3445	
8	3495	3544	3593	3643	3692	3742	3791	3841	3890	3939	
9	3989	4038	4088	4137	4186	4236	4285	4335	4384	4433	
880	4483	4532	4581	4631	4680	4729	4779	4828	4877	4927	
1	4976	5025	5074	5124	5173	5222	5272	5321	5370	5419	
2	5469	5518	5567	5616	5665	5715	5764	5813	5862	5912	
3	5961	6010	6059	6108	6157	6207	6256	6305	6354	6403	
4	6452	6501	6551	6600	6649	6698	6747	6796	6845	6894	
5	6943	6992	7041	7090	7139	7189	7238	7287	7336	7385	
6	7434	7483	7532	7581	7630	7679	7728	7777	7826	7875	49
7	7924	7973	8022	8070	8119	8168	8217	8266	8315	8364	
8	8413	8462	8511	8560	8608	8657	8706	8755	8804	8853	
9	8902	8951	8999	9048	9097	9146	9195	9244	9292	9341	
890	9390	9439	9488	9536	9585	9634	9683	9731	9780	9829	
1	9878	9926	9975	0024	0073	0121	0170	0219	0267	0316	
2	950365	0414	0462	0511	0560	0608	0657	0706	0754	0803	
3	0851	0900	0949	0997	1046	1095	1143	1192	1240	1289	
4	1338	1386	1435	1483	1532	1580	1629	1677	1726	1775	
5	1823	1872	1920	1969	2017	2066	2114	2163	2211	2260	
6	2308	2356	2405	2453	2502	2550	2599	2647	2696	2744	
7	2792	2841	2889	2938	2986	3034	3083	3131	3180	3228	
8	3276	3325	3373	3421	3470	3518	3566	3615	3663	3711	
9	3760	3808	3856	3905	3953	4001	4049	4098	4146	4194	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
51	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	45.9
50	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0
49	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.1
48	4.8	9.6	14.4	19.2	24.0	28.8	33.6	38.4	43.2

No 900 L. 954.]

[No. 944 L. 975.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
900	954243	4291	4339	4387	4435	4484	4532	4580	4628	4677	48
1	4725	4773	4821	4869	4918	4966	5014	5062	5110	5158	
2	5207	5255	5303	5351	5399	5447	5495	5543	5592	5640	
3	5688	5736	5784	5832	5880	5928	5976	6024	6072	6120	
4	6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	
5	6649	6697	6745	6793	6840	6888	6936	6984	7032	7080	
6	7128	7176	7224	7272	7320	7368	7416	7464	7512	7559	
7	7607	7655	7703	7751	7799	7847	7894	7942	7990	8038	
8	8086	8134	8181	8229	8277	8325	8373	8421	8468	8516	
9	8564	8612	8659	8707	8755	8803	8850	8898	8946	8994	
910	9041	9089	9137	9185	9232	9280	9328	9375	9423	9471	47
1	9518	9566	9614	9661	9709	9757	9804	9852	9900	9947	
2	9995										
3	960471	0042	0090	0138	0185	0233	0280	0328	0376	0423	
4	0946	0518	0566	0613	0661	0709	0756	0804	0851	0899	
5	1421	0994	1041	1089	1136	1184	1231	1279	1326	1374	
6	1895	1469	1516	1563	1611	1658	1706	1753	1801	1848	
7	2369	1943	1990	2038	2085	2132	2180	2227	2275	2322	
8	2843	2417	2464	2511	2559	2606	2653	2701	2748	2795	
9	3316	2890	2937	2985	3032	3079	3126	3174	3221	3268	
920	3788	3363	3410	3457	3504	3552	3599	3646	3693	3741	46
1	4260	3835	3882	3929	3977	4024	4071	4118	4165	4212	
2	4731	4307	4354	4401	4448	4495	4542	4590	4637	4684	
3	5202	4778	4825	4872	4919	4966	5013	5061	5108	5155	
4	5672	5249	5296	5343	5390	5437	5484	5531	5578	5625	
5	6142	5719	5766	5813	5860	5907	5954	6001	6048	6095	
6	6611	6189	6236	6283	6329	6376	6423	6470	6517	6564	
7	7080	6658	6705	6752	6799	6845	6892	6939	6986	7033	
8	7548	7127	7173	7220	7267	7314	7361	7408	7454	7501	
9	8016	7595	7642	7688	7735	7782	7829	7875	7922	7969	
930	8483	8062	8109	8156	8203	8249	8296	8343	8390	8436	46
1	8950	8530	8576	8623	8670	8716	8763	8810	8856	8903	
2	9416	8996	9043	9090	9136	9183	9229	9276	9323	9369	
3	9882	9463	9509	9556	9602	9649	9695	9742	9789	9835	
4	970347	0393	0440	0021	0068	0114	0161	0207	0254	0300	
5	0812	0858	0904	0486	0533	0579	0626	0672	0719	0765	
6	1276	1322	1369	0951	0997	1044	1090	1137	1183	1229	
7	1740	1786	1832	1415	1461	1508	1554	1601	1647	1693	
8	2203	2249	2295	1879	1925	1971	2018	2064	2110	2157	
9	2666	2712	2758	2342	2388	2434	2481	2527	2573	2619	
940	3128	2758	2804	2851	2897	2943	2989	3035	3082		
1	3590	3174	3220	3266	3313	3359	3405	3451	3497	3543	
2	4051	3636	3682	3728	3774	3820	3866	3913	3959	4005	
3	4512	4097	4143	4189	4235	4281	4327	4374	4420	4466	
4	4972	4558	4604	4650	4696	4742	4788	4834	4880	4926	
		5018	5064	5110	5156	5202	5248	5294	5340	5386	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
47	4.7	9.4	14.1	18.8	23.5	28.2	32.9	37.6	42.3
46	4.6	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41.4

106 TABLE XXIV.—LOGARITHMS OF NUMBERS

No. 945 L. 975.]

[No. 989 L. 995.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
945	975432	5478	5524	5570	5616	5662	5707	5753	5799	5845	
6	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	
7	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	
8	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	
9	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	
950	7724	7769	7815	7861	7906	7952	7998	8043	8089	8135	
1	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	
2	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	
3	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	
4	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	
5	980003	0049	0094	0140	0185	0231	0276	0322	0367	0412	
6	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	
7	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	
8	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	
9	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	
960	2271	2316	2362	2407	2452	2497	2543	2588	2633	2678	
1	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	
2	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	
3	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	
4	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	
5	4527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
6	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	
7	5428	5471	5516	5561	5606	5651	5696	5741	5786	5830	
8	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	
9	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	
970	6772	6817	6861	6906	6951	6996	7040	7085	7130	7175	
1	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	
2	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	
3	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	
4	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	
5	9005	9049	9094	9138	9183	9227	9272	9316	9361	9405	
6	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	
7	9895	9939	9983								
8	990339	0383	0428	0472	0516	0561	0605	0650	0694	0738	
9	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	
980	1226	1270	1315	1359	1403	1448	1492	1536	1580	1625	
1	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	
2	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	
3	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	
4	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	
5	3436	3480	3524	3568	3613	3657	3701	3745	3789	3833	
6	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	
7	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	
8	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	44
9	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
46	4.6	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41.4
45	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5
44	4.4	8.8	13.2	17.6	22.0	26.4	30.8	35.2	39.6
43	4.3	8.6	12.9	17.2	21.5	25.8	30.1	34.4	38.7

TABLE XXIV.—LOGARITHMS OF NUMBERS 107

No. 990 L. 995.]

[No. 999 L. 999]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
990	995635	5679	5723	5767	5811	5854	5898	5942	5986	6030	
1	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
2	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	
3	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	
4	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	
5	7823	7867	7910	7954	7998	8041	8085	8129	8172	8216	
6	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	
7	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	
8	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	
9	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43

LOGARITHMS OF NUMBERS FROM 1 TO 100.

N.	Log.	N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0.000000	21	1.322219	41	1.612784	61	1.785330	81	1.908485
2	0.301030	22	1.342423	42	1.623249	62	1.792392	82	1.913814
3	0.477121	23	1.361728	43	1.633468	63	1.799341	83	1.919078
4	0.602060	24	1.380211	44	1.643453	64	1.806180	84	1.924279
5	0.698970	25	1.397940	45	1.653213	65	1.812913	85	1.929419
6	0.778151	26	1.414973	46	1.662758	66	1.819544	86	1.934498
7	0.845098	27	1.431364	47	1.672098	67	1.826075	87	1.939519
8	0.903090	28	1.447158	48	1.681241	68	1.832509	88	1.944483
9	0.954243	29	1.462398	49	1.690196	69	1.838849	89	1.949390
10	1.000000	30	1.477121	50	1.698970	70	1.845098	90	1.954243
11	1.041393	31	1.491362	51	1.707570	71	1.851258	91	1.959041
12	1.079181	32	1.505150	52	1.716003	72	1.857332	92	1.963788
13	1.113943	33	1.518514	53	1.724276	73	1.863323	93	1.968483
14	1.146128	34	1.531479	54	1.732394	74	1.869232	94	1.973128
15	1.176091	35	1.544068	55	1.740363	75	1.875061	95	1.977724
16	1.204120	36	1.556303	56	1.748188	76	1.880814	96	1.982271
17	1.230449	37	1.568202	57	1.755875	77	1.886491	97	1.986772
18	1.255273	38	1.579784	58	1.763428	78	1.892095	98	1.991226
19	1.278754	39	1.591065	59	1.770852	79	1.897627	99	1.995635
20	1.301030	40	1.602060	60	1.778151	80	1.903090	100	2.000000

	Value at 0°.	Sign in 1st Quad.	Value at 90°.	Sign in 2d Quad.	Value at 180°.	Sign in 3d Quad.	Value at 270°.	Sign in 4th Quad.	Value at 360°.
Sin.....	O	+	R	+	O	-	R	-	O
Tan.....	O	+	R	-	O	+	R	+	O
Sec.....	R	+	R	-	R	+	R	+	R
Versin....	O	+	R	+	2 R	+	R	+	O
Cos.....	R	+	O	-	R	+	O	+	R
Cot.....	R	+	O	-	R	+	O	+	R
Cosec.....	R	+	R	+	R	-	R	-	R

R signifies equal to rad; ∞ signifies infinite; O signifies evanescent.

0°		Sine.	$q-l$	Tang.	Cotang.	$q+l$	D1"	Cosine. 179°	
"	"		4.685			15.314			"
0	0	Inf. neg.	575	575	Inf. neg.	425		ten	60
60	1	6.463726	575	575	6.463726	425		ten	59
120	2	.764756	575	575	.764756	425		ten	58
180	3	6.940847	575	575	6.940847	425		ten	57
240	4	7.065786	575	575	7.065786	425		ten	56
300	5	.162696	575	575	.162696	425		ten	55
360	6	.241877	575	575	.241877	425	.02	9.999999	54
420	7	.308824	575	575	.308825	425	.00	.999999	53
480	8	.366816	574	576	.366817	424	.00	.999999	52
540	9	.417968	574	576	.417970	424	.00	.999999	51
600	10	.463726	574	576	.463727	424	.02	.999998	50
660	11	7.505118	574	576	7.505120	424	.00	9.999998	49
720	12	.542906	574	577	.542909	423	.02	.999997	48
780	13	.577668	574	577	.577672	423	.00	.999997	47
840	14	.609853	574	577	.609857	423	.02	.999996	46
900	15	.639816	573	578	.639820	422	.00	.999996	45
960	16	.667845	573	578	.667849	422	.02	.999995	44
1020	17	.694173	573	578	.694179	422	.00	.999995	43
1080	18	.718997	573	579	.719003	421	.02	.999994	42
1140	19	.742478	573	579	.742484	421	.02	.999993	41
1200	20	.764754	572	580	.764761	420	.00	.999993	40
1260	21	7.785943	572	580	7.785951	420	.02	9.999992	39
1320	22	.806146	572	581	.806155	419	.02	.999991	38
1380	23	.825451	572	581	.825460	419	.02	.999990	37
1440	24	.842934	571	582	.843944	418	.02	.999989	36
1500	25	.861662	571	583	.861674	417	.00	.999989	35
1560	26	.878695	571	583	.878708	417	.02	.999988	34
1620	27	.895085	570	584	.895099	416	.02	.999987	33
1680	28	.910879	570	584	.910894	416	.02	.999986	32
1740	29	.926119	570	585	.926134	415	.02	.999985	31
1800	30	.940842	569	586	.940858	414	.03	.999983	30
1860	31	7.955082	569	587	7.955100	413	.02	9.999982	29
1920	32	.968870	569	587	.968889	413	.02	.999981	28
1980	33	.982233	568	588	.982253	412	.02	.999980	27
2040	34	7.995198	568	589	7.995219	411	.02	.999979	26
2100	35	8.007787	567	590	8.007809	410	.03	.999977	25
2160	36	.020021	567	591	.020044	409	.02	.999976	24
2220	37	.031919	566	592	.031945	408	.02	.999975	23
2280	38	.043501	566	593	.043527	407	.03	.999973	22
2340	39	.054781	566	593	.054809	407	.02	.999972	21
2400	40	.065776	565	594	.065806	406	.02	.999971	20
2460	41	8.076500	565	595	8.076531	405	.03	9.999969	19
2520	42	.086965	564	596	.086997	404	.02	.999968	18
2580	43	.097183	564	598	.097217	402	.03	.999966	17
2640	44	.107167	563	599	.107203	401	.03	.999964	16
2700	45	.116926	562	600	.116963	400	.02	.999963	15
2760	46	.126471	562	601	.126510	399	.03	.999961	14
2820	47	.135810	561	602	.135851	398	.03	.999959	13
2880	48	.144953	561	603	.144996	397	.02	.999958	12
2940	49	.153907	560	604	.153952	396	.03	.999956	11
3000	50	.162681	560	605	.162727	395	.03	.999954	10
3060	51	8.171280	559	607	8.171328	393	.03	9.999952	9
3120	52	.179713	558	608	.179763	392	.03	.999950	8
3180	53	.187985	558	609	.188036	391	.03	.999948	7
3240	54	.196102	557	611	.196156	389	.03	.999946	6
3300	55	.204070	556	612	.204126	388	.03	.999944	5
3360	56	.211895	556	613	.211953	387	.03	.999942	4
3420	57	.219581	555	615	.219641	385	.03	.999940	3
3480	58	.227134	554	616	.227195	384	.03	.999938	2
3540	59	.234557	554	618	.234621	382	.03	.999936	1
3600	60	8.241855	553	619	8.241921	381	.03	9.999934	0
"	"		4.685			15.314			"
90°		Cosine.	$q-l$	Cotang.	Tang.	$q+l$	D1"	Sine.	89°

1°		Sine.	q-l		Tang.	Cotang.	q+l	D1"	Cosine. 178°	
"	"		4.685				15.314			"
3600	0	8.241855	553	619	8.241921	11.758079	381	.03	9.999934	60
3660	1	.249033	552	620	.249102	.750898	380	.05	.999932	59
3720	2	.256094	551	622	.256165	.743835	378	.03	.999929	58
3780	3	.263042	551	623	.263115	.733385	377	.03	.999927	57
3840	4	.269881	550	625	.269956	.730044	375	.03	.999925	56
3900	5	.276614	549	627	.276691	.723309	373	.05	.999922	55
3960	6	.283243	548	628	.283323	.716677	372	.03	.999920	54
4020	7	.289773	547	630	.289856	.710144	370	.03	.999918	53
4080	8	.296207	546	632	.296292	.703708	368	.05	.999915	52
4140	9	.302546	546	633	.302634	.697366	367	.03	.999913	51
4200	10	.308794	545	635	.308884	.691116	365	.05	.999910	50
4260	11	8.314954	544	637	8.315046	11.684954	363	.05	9.999907	49
4320	12	.321027	543	638	.321122	.678878	362	.03	.999905	48
4380	13	.327016	542	640	.327114	.672886	360	.05	.999902	47
4440	14	.332924	541	642	.333025	.666975	358	.05	.999899	46
4500	15	.338753	540	644	.338856	.661144	356	.03	.999897	45
4560	16	.344504	539	646	.344610	.655390	354	.05	.999894	44
4620	17	.350181	539	648	.350289	.649711	352	.05	.999891	43
4680	18	.355783	538	649	.355895	.644105	351	.05	.999888	42
4740	19	.361315	537	651	.361430	.638570	349	.05	.999885	41
4800	20	.366777	536	653	.366895	.633105	347	.05	.999882	40
4860	21	8.372171	535	655	8.372292	11.627708	345	.05	9.999879	39
4920	22	.377499	534	657	.377622	.622378	343	.05	.999876	38
4980	23	.382762	533	659	.382889	.617111	341	.05	.999873	37
5040	24	.387962	532	661	.388092	.611908	339	.05	.999870	36
5100	25	.393101	531	663	.393234	.606766	337	.05	.999867	35
5160	26	.398179	530	666	.398315	.601685	334	.05	.999864	34
5220	27	.403199	529	668	.403338	.596662	332	.05	.999861	33
5280	28	.408161	527	670	.408304	.591696	330	.05	.999858	32
5340	29	.413068	526	672	.413213	.586787	328	.07	.999854	31
5400	30	.417919	525	674	.418068	.581932	326	.05	.999851	30
5460	31	8.422717	524	676	8.422869	11.577131	324	.05	9.999848	29
5520	32	.427462	523	679	.427618	.572382	321	.07	.999844	28
5580	33	.432156	522	681	.432315	.567685	319	.05	.999841	27
5640	34	.436800	521	683	.436962	.563038	317	.05	.999838	26
5700	35	.441394	520	685	.441560	.558440	315	.07	.999834	25
5760	36	.445941	518	688	.446110	.553890	312	.05	.999831	24
5820	37	.450440	517	690	.450613	.549387	310	.07	.999827	23
5880	38	.454893	516	693	.455070	.544930	307	.05	.999824	22
5940	39	.459301	515	695	.459481	.540519	305	.07	.999820	21
6000	40	.463665	514	697	.463849	.536151	303	.07	.999816	20
6060	41	8.467985	512	700	8.468172	11.531828	300	.05	9.999813	19
6120	42	.472263	511	702	.472454	.527546	298	.07	.999809	18
6180	43	.476498	510	705	.476693	.523307	295	.07	.999805	17
6240	44	.480693	509	707	.480892	.519108	293	.07	.999801	16
6300	45	.484848	507	710	.485050	.514950	290	.05	.999797	15
6360	46	.488963	506	713	.489170	.510830	287	.07	.999794	14
6420	47	.493040	505	715	.493250	.506750	285	.07	.999790	13
6480	48	.497078	503	718	.497293	.502707	282	.07	.999786	12
6540	49	.501080	502	720	.501298	.498702	280	.07	.999782	11
6600	50	.505045	501	723	.505267	.494733	277	.07	.999778	10
6660	51	8.508974	499	726	8.509200	11.490800	274	.07	9.999774	9
6720	52	.512867	498	729	.513098	.486902	271	.08	.999769	8
6780	53	.516726	497	731	.516961	.483039	269	.07	.999765	7
6840	54	.520551	495	734	.520790	.479210	266	.07	.999761	6
6900	55	.524343	494	737	.524586	.475414	263	.07	.999757	5
6960	56	.528102	492	740	.528349	.471651	260	.07	.999753	4
7020	57	.531828	491	743	.532080	.467920	257	.08	.999748	3
7080	58	.535523	490	745	.535779	.464221	255	.07	.999744	2
7140	59	.539186	488	748	.539447	.460553	252	.07	.999740	1
7200	60	8.542819	487	751	8.543084	11.456916	249	.08	9.999735	0
"	"		4.685				15.314			"
91°		Cosine.	q-l		Cotang.	Tang.	q+l	D1"	Sine.	88°

2°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	177°
0'	8.542819	60.05	9.999735	.07	8.543084	60.12	11.456916	60'
1	.546422	59.55	.999731	.08	.546691	59.62	.453309	59
2	.549995	59.07	.999726	.07	.550268	59.15	.449732	58
3	.553539	58.58	.999722	.08	.553817	58.65	.446183	57
4	.557054	58.10	.999717	.07	.557336	58.20	.442664	56
5	.560540	57.65	.999713	.08	.560828	57.72	.439172	55
6	.563999	57.20	.999708	.07	.564291	57.27	.435709	54
7	.567431	56.75	.999704	.08	.567727	56.83	.432273	53
8	.570836	56.30	.999699	.07	.571137	56.38	.428863	52
9	.574214	55.87	.999694	.08	.574520	55.95	.425480	51
10	.577566	55.43	.999689	.07	.577877	55.52	.422123	50
11	8.580892	55.02	9.999685	.08	8.581208	55.10	11.418792	49
12	.584193	54.60	.999680	.07	.584514	54.68	.415486	48
13	.587469	54.20	.999675	.08	.587795	54.27	.412205	47
14	.590721	53.78	.999670	.07	.591051	53.87	.408949	46
15	.593948	53.40	.999665	.08	.594283	53.48	.405717	45
16	.597152	53.00	.999660	.07	.597492	53.08	.402508	44
17	.600332	52.62	.999655	.08	.600677	52.70	.399323	43
18	.603489	52.23	.999650	.07	.603839	52.32	.396161	42
19	.606623	51.85	.999645	.08	.606978	51.93	.393022	41
20	.609734	51.48	.999640	.07	.610094	51.58	.389906	40
21	8.612823	51.13	9.999635	.10	8.613189	51.22	11.386811	39
22	.615891	50.77	.999629	.08	.616262	50.85	.383738	38
23	.618937	50.42	.999624	.07	.619313	50.50	.380687	37
24	.621962	50.05	.999619	.08	.622343	50.15	.377657	36
25	.624965	49.72	.999614	.07	.625352	49.80	.374648	35
26	.627948	49.38	.999608	.08	.628340	49.47	.371660	34
27	.630911	49.05	.999603	.07	.631308	49.13	.368692	33
28	.633854	48.70	.999597	.08	.634256	48.80	.365744	32
29	.636776	48.40	.999592	.07	.637184	48.48	.362816	31
30	.639680	48.05	.999586	.08	.640093	48.15	.359907	30
31	8.642563	47.75	9.999581	.10	8.642982	47.85	11.357018	29
32	.645428	47.43	.999575	.08	.645853	47.52	.354147	28
33	.648274	47.13	.999570	.07	.648704	47.22	.351296	27
34	.651102	46.82	.999564	.08	.651537	46.92	.348463	26
35	.653911	46.52	.999558	.07	.654352	46.62	.345648	25
36	.656702	46.22	.999553	.08	.657149	46.32	.342851	24
37	.659475	45.92	.999547	.07	.659928	46.02	.340072	23
38	.662230	45.63	.999541	.08	.662689	45.73	.337311	22
39	.664968	45.35	.999535	.07	.665433	45.45	.334567	21
40	.667689	45.07	.999529	.08	.668160	45.17	.331840	20
41	8.670393	44.78	9.999524	.10	8.670870	44.88	11.329130	19
42	.673080	44.52	.999518	.08	.673563	44.60	.326437	18
43	.675751	44.23	.999512	.07	.676239	44.35	.323761	17
44	.678405	43.97	.999506	.08	.678900	44.07	.321100	16
45	.681043	43.70	.999500	.07	.681544	43.80	.318456	15
46	.683665	43.45	.999493	.08	.684172	43.53	.315828	14
47	.686272	43.18	.999487	.07	.686784	43.28	.313216	13
48	.688863	42.92	.999481	.08	.689381	43.03	.310619	12
49	.691438	42.67	.999475	.07	.691963	42.77	.308037	11
50	.693998	42.42	.999469	.08	.694529	42.53	.305471	10
51	8.696543	42.17	9.999463	.12	8.697081	42.27	11.302919	9
52	.699073	41.93	.999456	.10	.699617	42.03	.300383	8
53	.701589	41.68	.999450	.12	.702139	41.78	.297861	7
54	.704090	41.45	.999443	.10	.704646	41.57	.295354	6
55	.706577	41.20	.999437	.12	.707140	41.30	.292860	5
56	.709049	40.97	.999431	.10	.709618	41.08	.290382	4
57	.711507	40.75	.999424	.12	.712083	40.85	.287917	3
58	.713952	40.52	.999416	.10	.714534	40.63	.285466	2
59	.716383	40.28	.999411	.12	.716972	40.40	.283023	1
60'	8.718800		9.999404		8.719396		11.280604	0'
92°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	87°

3°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	176°
0'	8.718800		9.999404		8.719396		11.280604	60'
1	.721204	40.07	.999398	.10	.721806	40.17	.278194	59
2	.723595	39.85	.999391	.12	.724204	39.97	.275796	58
3	.725972	39.62	.999384	.12	.726588	39.73	.273412	57
4	.728337	39.42	.999378	.10	.728959	39.52	.271041	56
5	.730688	39.18	.999371	.12	.731317	39.30	.268683	55
6	.733027	38.98	.999364	.12	.733663	39.10	.266337	54
7	.735354	38.78	.999357	.12	.735996	38.88	.264004	53
8	.737667	38.55	.999350	.12	.738317	38.68	.261683	52
9	.739969	38.37	.999343	.12	.740626	38.48	.259374	51
10	.742259	38.17	.999336	.12	.742922	38.27	.257078	50
		37.95		.12		38.08		
11	8.744536		9.999329		8.745207		11.254793	49
12	.746802	37.77	.999322	.12	.747479	37.87	.252521	48
13	.749055	37.55	.999315	.12	.749740	37.68	.250260	47
14	.751297	37.37	.999308	.12	.751989	37.48	.248011	46
15	.753528	37.18	.999301	.12	.754227	37.30	.245773	45
16	.755747	36.98	.999294	.12	.756453	37.10	.243547	44
17	.757955	36.80	.999287	.12	.758668	36.92	.241332	43
18	.760151	36.60	.999279	.13	.760872	36.73	.239128	42
19	.762337	36.43	.999272	.12	.763065	36.55	.236935	41
20	.764511	36.23	.999265	.12	.765246	36.35	.234754	40
		36.07		.13		36.18		
21	8.766675		9.999257		8.767417		11.232583	39
22	.768828	35.88	.999250	.12	.769578	36.02	.230422	38
23	.770970	35.70	.999242	.13	.771727	35.82	.228273	37
24	.773101	35.52	.999235	.12	.773866	35.65	.226134	36
25	.775223	35.37	.999227	.13	.775995	35.48	.224005	35
26	.777333	35.17	.999220	.12	.778114	35.32	.221886	34
27	.779434	35.02	.999212	.13	.780222	35.13	.219778	33
28	.781524	34.83	.999205	.12	.782320	34.97	.217680	32
29	.783605	34.68	.999197	.13	.784408	34.80	.215592	31
30	.785675	34.50	.999189	.13	.786486	34.63	.213514	30
		34.35		.13		34.47		
31	8.787736		9.999181		8.788554		11.211446	29
32	.789787	34.18	.999174	.12	.790613	34.32	.209387	28
33	.791828	34.02	.999166	.13	.792662	34.15	.207338	27
34	.793859	33.85	.999158	.13	.794701	33.98	.205299	26
35	.795881	33.70	.999150	.13	.796731	33.83	.203269	25
36	.797894	33.55	.999142	.13	.798752	33.68	.201248	24
37	.799897	33.38	.999134	.13	.800763	33.52	.199237	23
38	.801892	33.25	.999126	.13	.802765	33.37	.197235	22
39	.803876	33.07	.999118	.13	.804758	33.22	.195242	21
40	.805852	32.93	.999110	.13	.806742	33.07	.193258	20
		32.78		.13		32.92		
41	8.807819		9.999102		8.808717		11.191283	19
42	.809777	32.63	.999094	.13	.810683	32.77	.189317	18
43	.811726	32.48	.999086	.13	.812641	32.63	.187359	17
44	.813667	32.35	.999077	.15	.814589	32.47	.185411	16
45	.815599	32.20	.999069	.13	.816529	32.33	.183471	15
46	.817522	32.05	.999061	.13	.818461	32.20	.181539	14
47	.819436	31.90	.999053	.13	.820384	32.05	.179616	13
48	.821343	31.78	.999044	.15	.822298	31.90	.177702	12
49	.823240	31.62	.999036	.13	.824205	31.78	.175795	11
50	.825130	31.50	.999027	.15	.826103	31.63	.173897	10
		31.35		.13		31.48		
51	8.827011		9.999019		8.827992		11.172008	9
52	.828884	31.22	.999010	.15	.829874	31.37	.170126	8
53	.830749	31.08	.999002	.13	.831748	31.23	.168252	7
54	.832607	30.97	.998993	.15	.833613	31.08	.166387	6
55	.834456	30.82	.998984	.15	.835471	30.97	.164529	5
56	.836297	30.68	.998976	.13	.837321	30.83	.162679	4
57	.838130	30.55	.998967	.15	.839163	30.70	.160837	3
58	.839956	30.43	.998958	.15	.840998	30.58	.159002	2
59	.841774	30.30	.998950	.13	.842825	30.45	.157175	1
60'	8.843585		9.998941		8.844644		11.155356	0'
		30.18		.15		30.32		
93°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	86°

4°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	175°
0'	8.843585	30.03	9.998941	.15	8.844644	30.18	11.155356	60'
1	.845387	29.93	.998932	.15	.846455	30.08	.153545	59
2	.847183	29.80	.998923	.15	.848260	29.95	.151740	58
3	.848971	29.67	.998914	.15	.850057	29.82	.149943	57
4	.850751	29.57	.998905	.15	.851846	29.70	.148154	56
5	.852525	29.43	.998896	.15	.853628	29.58	.146372	55
6	.854291	29.30	.998887	.15	.855403	29.47	.144597	54
7	.856049	29.20	.998878	.15	.857171	29.35	.142829	53
8	.857801	29.08	.998869	.15	.858932	29.23	.141068	52
9	.859546	28.95	.998860	.15	.860686	29.12	.139314	51
10	.861283	28.85	.998851	.17	.862433	29.00	.137567	50
11	8.863014	28.73	9.998841	.15	8.864173	28.88	11.135827	49
12	.864738	28.62	.998832	.15	.865906	28.77	.134094	48
13	.866455	28.50	.998823	.17	.867632	28.65	.132368	47
14	.868165	28.38	.998813	.15	.869351	28.55	.130649	46
15	.869868	28.28	.998804	.15	.871064	28.43	.128936	45
16	.871565	28.17	.998795	.17	.872770	28.32	.127230	44
17	.873255	28.05	.998785	.15	.874469	28.22	.125531	43
18	.874938	27.95	.998776	.17	.876162	28.12	.123838	42
19	.876615	27.83	.998766	.15	.877849	28.00	.122151	41
20	.878285	27.73	.998757	.17	.879529	27.88	.120471	40
21	8.879949	27.63	9.998747	.15	8.881202	27.78	11.118798	39
22	.881607	27.52	.998738	.17	.882869	27.68	.117131	38
23	.883258	27.42	.998728	.17	.884530	27.58	.115470	37
24	.884903	27.32	.998718	.17	.886185	27.47	.113815	36
25	.886542	27.20	.998708	.15	.887833	27.38	.112167	35
26	.888174	27.12	.998699	.17	.889476	27.27	.110524	34
27	.889801	27.00	.998689	.17	.891112	27.17	.108888	33
28	.891421	26.90	.998679	.17	.892742	27.07	.107258	32
29	.893035	26.80	.998669	.17	.894366	26.97	.105634	31
30	.894643	26.72	.998659	.17	.895984	26.87	.104016	30
31	8.896246	26.60	9.998649	.17	8.897596	26.78	11.102404	29
32	.897842	26.50	.998639	.17	.899203	26.67	.100797	28
33	.899432	26.42	.998629	.17	.900803	26.58	.099197	27
34	.901017	26.32	.998619	.17	.902398	26.48	.097602	26
35	.902596	26.22	.998609	.17	.903987	26.38	.096013	25
36	.904169	26.12	.998599	.17	.905570	26.28	.094430	24
37	.905736	26.02	.998589	.18	.907147	26.20	.092853	23
38	.907297	25.93	.998578	.17	.908719	26.10	.091281	22
39	.908853	25.85	.998568	.17	.910285	26.02	.089715	21
40	.910404	25.75	.998558	.17	.911846	25.92	.088154	20
41	8.911949	25.65	9.998548	.18	8.913401	25.83	11.086599	19
42	.913488	25.57	.998537	.17	.914951	25.73	.085049	18
43	.915022	25.47	.998527	.18	.916495	25.65	.083505	17
44	.916550	25.38	.998516	.17	.918034	25.57	.081966	16
45	.918073	25.30	.998506	.18	.919568	25.47	.080432	15
46	.919591	25.20	.998495	.17	.921096	25.38	.078904	14
47	.921103	25.12	.998485	.18	.922619	25.28	.077381	13
48	.922610	25.03	.998474	.17	.924136	25.22	.075864	12
49	.924112	24.95	.998464	.18	.925649	25.12	.074351	11
50	.925609	24.85	.998453	.18	.927156	25.03	.072844	10
51	8.927100	24.78	9.998442	.18	8.928658	24.95	11.071342	9
52	.928587	24.68	.998431	.17	.930155	24.87	.069845	8
53	.930068	24.60	.998421	.18	.931647	24.78	.068353	7
54	.931544	24.52	.998410	.18	.933134	24.70	.066866	6
55	.933015	24.43	.998399	.18	.934616	24.62	.065384	5
56	.934481	24.35	.998388	.18	.936093	24.53	.063907	4
57	.935942	24.27	.998377	.18	.937565	24.45	.062435	3
58	.937398	24.20	.998366	.18	.939032	24.37	.060968	2
59	.938850	24.10	.998355	.18	.940494	24.30	.059506	1
60'	8.940296		9.998344	.18	8.941952		11.058048	0'
44°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	85°

5°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 174°	
0'	8.940296		9.998344		8.941952		11.058048	60'
1	.941738	24.03	.998333	.18	.943404	24.20	.056596	59
2	.943174	23.93	.998322	.18	.944852	24.13	.055148	58
3	.944606	23.87	.998311	.18	.946295	24.05	.053705	57
4	.946034	23.80	.998300	.18	.947734	23.98	.052266	56
5	.947456	23.70	.998289	.18	.949168	23.90	.050832	55
6	.948874	23.63	.998277	.20	.950597	23.82	.049403	54
7	.950287	23.55	.998266	.18	.952021	23.73	.047979	53
8	.951696	23.48	.998255	.18	.953441	23.67	.046559	52
9	.953100	23.40	.998243	.20	.954856	23.58	.045144	51
10	.954499	23.32	.998232	.18	.956267	23.52	.043733	50
		23.25		.20		23.45		
11	8.955894		9.998220		8.957674		11.042326	49
12	.957284	23.17	.998209	.18	.959075	23.35	.040925	48
13	.958670	23.10	.998197	.20	.960473	23.30	.039527	47
14	.960052	23.03	.998186	.18	.961866	23.22	.038134	46
15	.961429	22.95	.998174	.20	.963255	23.15	.036745	45
16	.962801	22.87	.998163	.18	.964639	23.07	.035361	44
17	.964170	22.82	.998151	.20	.966019	23.00	.033981	43
18	.965534	22.73	.998139	.20	.967394	22.92	.032606	42
19	.966893	22.65	.998128	.18	.968766	22.87	.031234	41
20	.968249	22.60	.998116	.20	.970133	22.78	.029867	40
		22.52		.20		22.72		
21	8.969600		9.998104		8.971496		11.028504	39
22	.970947	22.45	.998092	.20	.972855	22.65	.027145	38
23	.972289	22.37	.998080	.20	.974209	22.57	.025791	37
24	.973628	22.32	.998068	.20	.975560	22.52	.024440	36
25	.974962	22.23	.998056	.20	.976906	22.43	.023094	35
26	.976293	22.18	.998044	.20	.978248	22.37	.021752	34
27	.977619	22.10	.998032	.20	.979586	22.30	.020414	33
28	.978941	22.03	.998020	.20	.980921	22.25	.019079	32
29	.980259	21.97	.998008	.20	.982251	22.17	.017749	31
30	.981573	21.90	.997996	.20	.983577	22.10	.016423	30
		21.83		.20		22.03		
31	8.982883		9.997984		8.984899		11.015101	29
32	.984189	21.77	.997972	.20	.986217	21.97	.013783	28
33	.985491	21.70	.997959	.22	.987532	21.92	.012468	27
34	.986789	21.63	.997947	.20	.988842	21.83	.011158	26
35	.988083	21.57	.997935	.20	.990149	21.78	.009851	25
36	.989374	21.52	.997922	.22	.991451	21.70	.008549	24
37	.990660	21.43	.997910	.20	.992750	21.65	.007250	23
38	.991943	21.38	.997897	.22	.994045	21.58	.005955	22
39	.993222	21.32	.997885	.20	.995337	21.53	.004663	21
40	.994497	21.25	.997872	.22	.996624	21.45	.003376	20
		21.18		.20		21.40		
41	8.995768		9.997860		8.997908		11.002092	19
42	.997036	21.13	.997847	.22	8.999188	21.33	11.000812	18
43	.998299	21.05	.997835	.20	9.000465	21.28	10.999535	17
44	8.999560		.997822	.22	.001738	21.22	.998262	16
45	9.000816	20.93	.997809	.22	.003007	21.15	.996993	15
46	.002069	20.88	.997797	.20	.004272	21.08	.995728	14
47	.003318	20.82	.997784	.22	.005534	21.03	.994466	13
48	.004563	20.75	.997771	.22	.006792	20.97	.993208	12
49	.005805	20.70	.997758	.22	.008047	20.92	.991953	11
50	.007044	20.65	.997745	.22	.009298	20.85	.990702	10
		20.57		.22		20.80		
51	9.008278		9.997732		9.010546		10.989454	9
52	.009510	20.53	.997719	.22	.011790	20.73	.988210	8
53	.010737	20.45	.997706	.22	.013031	20.68	.986969	7
54	.011962	20.42	.997693	.22	.014268	20.62	.985732	6
55	.013182	20.33	.997680	.22	.015502	20.57	.984498	5
56	.014400	20.30	.997667	.22	.016732	20.50	.983268	4
57	.015613	20.22	.997654	.22	.017959	20.45	.982041	3
58	.016824	20.18	.997641	.22	.019183	20.40	.980817	2
59	.018031	20.12	.997628	.22	.020403	20.33	.979597	1
60'	9.019235	20.07	9.997614	.23	9.021620	20.28	10.978380	0'
95°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	84°

6°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	173°
0'	9.019235	20.00	9.997614	.22	9.021620	20.23	10.978380	60'
1	.020435	19.95	.997601	.22	.022834	20.17	.977166	59
2	.021632	19.88	.997588	.23	.024044	20.12	.975956	58
3	.022825	19.85	.997574	.22	.025251	20.07	.974749	57
4	.024016	19.78	.997561	.23	.026455	20.00	.973545	56
5	.025203	19.72	.997547	.22	.027655	19.95	.972345	55
6	.026386	19.68	.997534	.23	.028852	19.90	.971148	54
7	.027567	19.62	.997520	.22	.030046	19.85	.969954	53
8	.028744	19.57	.997507	.23	.031237	19.80	.968763	52
9	.029918	19.52	.997493	.22	.032425	19.73	.967575	51
10	.031089	19.47	.997480	.23	.033609	19.70	.966391	50
11	9.032257	19.40	9.997466	.23	9.034791	19.63	10.965209	49
12	.033421	19.35	.997452	.22	.035969	19.58	.964031	48
13	.034582	19.32	.997439	.23	.037144	19.53	.962856	47
14	.035741	19.25	.997425	.23	.038316	19.48	.961684	46
15	.036896	19.20	.997411	.23	.039485	19.43	.960515	45
16	.038048	19.15	.997397	.23	.040651	19.37	.959349	44
17	.039197	19.08	.997383	.23	.041813	19.33	.958187	43
18	.040342	19.05	.997369	.23	.042973	19.28	.957027	42
19	.041485	19.00	.997355	.23	.044130	19.23	.955870	41
20	.042625	18.95	.997341	.23	.045284	19.17	.954716	40
21	9.043762	18.88	9.997327	.23	9.046434	19.13	10.953566	39
22	.044895	18.85	.997313	.23	.047582	19.08	.952418	38
23	.046026	18.80	.997299	.23	.048727	19.03	.951273	37
24	.047154	18.75	.997285	.23	.049869	18.98	.950131	36
25	.048279	18.68	.997271	.23	.051008	18.93	.948992	35
26	.049400	18.65	.997257	.25	.052144	18.88	.947856	34
27	.050519	18.60	.997242	.23	.053277	18.83	.946723	33
28	.051635	18.57	.997228	.23	.054407	18.80	.945593	32
29	.052749	18.50	.997214	.25	.055535	18.73	.944465	31
30	.053859	18.45	.997199	.23	.056659	18.70	.943341	30
31	9.054966	18.42	9.997185	.25	9.057781	18.65	10.942219	29
32	.056071	18.35	.997170	.23	.058900	18.60	.941100	28
33	.057172	18.32	.997156	.25	.060016	18.57	.939984	27
34	.058271	18.27	.997141	.23	.061130	18.50	.938870	26
35	.059367	18.22	.997127	.25	.062240	18.47	.937760	25
36	.060460	18.18	.997112	.25	.063348	18.42	.936652	24
37	.061551	18.13	.997098	.23	.064453	18.38	.935547	23
38	.062639	18.08	.997083	.25	.065556	18.32	.934444	22
39	.063724	18.03	.997068	.25	.066655	18.28	.933345	21
40	.064806	17.98	.997053	.23	.067752	18.23	.932248	20
41	9.065885	17.95	9.997039	.25	9.068846	18.20	10.931154	19
42	.066962	17.90	.997024	.25	.069938	18.15	.930062	18
43	.068036	17.85	.997009	.25	.071027	18.10	.928973	17
44	.069107	17.82	.996994	.25	.072113	18.07	.927887	16
45	.070176	17.77	.996979	.25	.073197	18.02	.926803	15
46	.071242	17.73	.996964	.25	.074278	17.97	.925722	14
47	.072306	17.67	.996949	.25	.075356	17.93	.924644	13
48	.073366	17.63	.996934	.25	.076432	17.88	.923568	12
49	.074424	17.60	.996919	.25	.077505	17.85	.922495	11
50	.075480	17.55	.996904	.25	.078576	17.80	.921424	10
51	9.076533	17.50	9.996889	.25	9.079644	17.77	10.920356	9
52	.077583	17.47	.996874	.27	.080710	17.72	.919290	8
53	.078631	17.42	.996858	.25	.081773	17.67	.918227	7
54	.079676	17.38	.996843	.27	.082833	17.63	.917167	6
55	.080719	17.33	.996828	.27	.083891	17.60	.916109	5
56	.081759	17.30	.996812	.25	.084947	17.55	.915053	4
57	.082797	17.25	.996797	.25	.086000	17.50	.914000	3
58	.083832	17.20	.996782	.27	.087050	17.47	.912950	2
59	.084864	17.17	.996766	.25	.088098	17.43	.911902	1
60'	9.085894		9.996751	.25	9.089144		10.910856	0'
96°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	83°

7°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	172°
0'	9.085894		9.996751		9.089144		10.910856	60'
1	.086922	17.13	.996735	.27	.090187	17.38	.909813	59
2	.087947	17.08	.996720	.25	.091228	17.35	.908772	58
3	.088970	17.05	.996704	.27	.092266	17.30	.907734	57
4	.089990	17.00	.996688	.27	.093302	17.27	.906698	56
5	.091008	16.97	.996673	.25	.094336	17.23	.905664	55
6	.092024	16.93	.996657	.27	.095367	17.18	.904633	54
7	.093037	16.88	.996641	.27	.096395	17.13	.903605	53
8	.094047	16.83	.996625	.27	.097422	17.12	.902578	52
9	.095056	16.82	.996610	.25	.098446	17.07	.901554	51
10	.096062	16.77	.996594	.27	.099468	17.03	.900532	50
		16.72		.27		16.98		
11	9.097065		9.996578		9.100487		10.899513	49
12	.098066	16.68	.996562	.27	.101504	16.95	.898496	48
13	.099065	16.65	.996546	.27	.102519	16.92	.897481	47
14	.100062	16.62	.996530	.27	.103532	16.88	.896468	46
15	.101056	16.57	.996514	.27	.104542	16.83	.895458	45
16	.102048	16.53	.996498	.27	.105550	16.80	.894450	44
17	.103037	16.48	.996482	.27	.106556	16.77	.893444	43
18	.104025	16.47	.996465	.28	.107559	16.72	.892441	42
19	.105010	16.42	.996449	.27	.108560	16.68	.891440	41
20	.105992	16.37	.996433	.27	.109559	16.65	.890441	40
		16.35		.27		16.62		
21	9.106973		9.996417		9.110556		10.889444	39
22	.107951	16.30	.996400	.28	.111551	16.58	.888449	38
23	.108927	16.27	.996384	.27	.112543	16.53	.887457	37
24	.109901	16.23	.996368	.27	.113533	16.50	.886467	36
25	.110873	16.20	.996351	.28	.114521	16.47	.885479	35
26	.111842	16.15	.996335	.27	.115507	16.43	.884493	34
27	.112809	16.12	.996318	.28	.116491	16.40	.883509	33
28	.113774	16.08	.996302	.27	.117472	16.35	.882528	32
29	.114737	16.05	.996285	.28	.118452	16.33	.881548	31
30	.115698	16.02	.996269	.27	.119429	16.28	.880571	30
		15.97		.28		16.25		
31	9.116656		9.996252		9.120404		10.879596	29
32	.117613	15.95	.996235	.28	.121377	16.22	.878623	28
33	.118567	15.90	.996219	.27	.122348	16.18	.877652	27
34	.119519	15.87	.996202	.28	.123317	16.15	.876683	26
35	.120469	15.83	.996185	.28	.124284	16.12	.875716	25
36	.121417	15.80	.996168	.28	.125249	16.08	.874751	24
37	.122362	15.75	.996151	.28	.126211	16.03	.873789	23
38	.123306	15.73	.996134	.28	.127172	16.02	.872828	22
39	.124248	15.70	.996117	.28	.128130	15.97	.871870	21
40	.125187	15.65	.996100	.28	.129087	15.95	.870913	20
		15.63		.28		15.90		
41	9.126125		9.996083		9.130041		10.869959	19
42	.127060	15.58	.996066	.28	.130994	15.88	.869006	18
43	.127993	15.55	.996049	.28	.131944	15.83	.868056	17
44	.128925	15.53	.996032	.28	.132893	15.82	.867107	16
45	.129854	15.48	.996015	.28	.133839	15.77	.866161	15
46	.130781	15.45	.995998	.28	.134784	15.75	.865216	14
47	.131706	15.42	.995980	.30	.135726	15.70	.864274	13
48	.132630	15.40	.995963	.28	.136667	15.68	.863333	12
49	.133551	15.35	.995946	.28	.137605	15.63	.862395	11
50	.134470	15.32	.995928	.30	.138542	15.62	.861458	10
		15.28		.28		15.57		
51	9.135387		9.995911		9.139476		10.860524	9
52	.136303	15.27	.995894	.28	.140409	15.55	.859591	8
53	.137216	15.22	.995876	.30	.141340	15.52	.858660	7
54	.138128	15.20	.995859	.28	.142269	15.48	.857731	6
55	.139037	15.15	.995841	.30	.143196	15.45	.856804	5
56	.139944	15.12	.995823	.30	.144121	15.42	.855879	4
57	.140850	15.10	.995806	.28	.145044	15.38	.854956	3
58	.141754	15.07	.995788	.30	.145966	15.37	.854034	2
59	.142655	15.02	.995771	.28	.146885	15.32	.853115	1
60'	9.143555	15.00	9.995753	.30	9.147803	15.30	10.852197	0'
97°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	82°

8°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 171°	
0'	9.143555	14.97	9.995753	.30	9.147803	15.25	10.852197	60'
1	.144453	14.93	.995735	.30	.148718	15.23	.851282	59
2	.145349	14.90	.995717	.30	.149632	15.20	.850368	58
3	.146243	14.88	.995699	.30	.150544	15.17	.849456	57
4	.147136	14.83	.995681	.28	.151454	15.15	.848546	56
5	.148026	14.83	.995664	.30	.152363	15.10	.847637	55
6	.148915	14.82	.995646	.30	.153269	15.08	.846731	54
7	.149802	14.78	.995628	.30	.154174	15.05	.845826	53
8	.150688	14.73	.995610	.32	.155077	15.02	.844923	52
9	.151569	14.72	.995591	.30	.155978	14.98	.844022	51
10	.152451	14.70	.995573	.30	.156877	14.97	.843123	50
11	9.153330	14.65	9.995555	.30	9.157775	14.93	10.842225	49
12	.154208	14.63	.995537	.30	.158671	14.90	.841329	48
13	.155083	14.58	.995519	.30	.159565	14.87	.840435	47
14	.155957	14.57	.995501	.32	.160457	14.83	.839543	46
15	.156830	14.55	.995482	.32	.161347	14.82	.838653	45
16	.157700	14.50	.995464	.30	.162236	14.78	.837764	44
17	.158569	14.48	.995446	.30	.163123	14.78	.836877	43
18	.159435	14.43	.995427	.32	.164008	14.75	.835992	42
19	.160301	14.43	.995409	.30	.164892	14.73	.835108	41
20	.161164	14.38	.995390	.32	.165774	14.70	.834226	40
21	9.162025	14.35	9.995372	.30	9.166654	14.67	10.833346	39
22	.162885	14.33	.995353	.32	.167532	14.63	.832468	38
23	.163743	14.30	.995334	.32	.168409	14.62	.831591	37
24	.164600	14.28	.995316	.30	.169284	14.58	.830716	36
25	.165454	14.23	.995297	.32	.170157	14.55	.829843	35
26	.166307	14.22	.995278	.32	.171029	14.53	.828971	34
27	.167159	14.20	.995260	.30	.171899	14.50	.828101	33
28	.168008	14.15	.995241	.32	.172767	14.47	.827233	32
29	.168856	14.13	.995222	.32	.173634	14.45	.826366	31
30	.169702	14.10	.995203	.32	.174499	14.42	.825501	30
31	9.170547	14.08	9.995184	.32	9.175362	14.38	10.824638	29
32	.171389	14.03	.995165	.32	.176224	14.37	.823776	28
33	.172230	14.02	.995146	.32	.177084	14.33	.822916	27
34	.173070	14.00	.995127	.32	.177942	14.30	.822058	26
35	.173908	13.97	.995108	.32	.178799	14.28	.821201	25
36	.174744	13.93	.995089	.32	.179655	14.27	.820345	24
37	.175578	13.90	.995070	.32	.180508	14.22	.819492	23
38	.176411	13.88	.995051	.32	.181360	14.20	.818640	22
39	.177242	13.85	.995032	.32	.182211	14.18	.817789	21
40	.178072	13.83	.995013	.32	.183059	14.13	.816941	20
41	9.178900	13.80	9.994993	.33	9.183907	14.13	10.816093	19
42	.179726	13.77	.994974	.32	.184752	14.08	.815248	18
43	.180551	13.75	.994955	.32	.185597	14.08	.814403	17
44	.181374	13.72	.994935	.33	.186439	14.03	.813561	16
45	.182196	13.70	.994916	.32	.187280	14.02	.812720	15
46	.183016	13.67	.994896	.33	.188120	14.00	.811880	14
47	.183834	13.63	.994877	.32	.188958	13.97	.811042	13
48	.184651	13.62	.994857	.33	.189794	13.93	.810206	12
49	.185466	13.58	.994838	.32	.190629	13.92	.809371	11
50	.186280	13.57	.994818	.33	.191462	13.88	.808538	10
51	9.187092	13.53	9.994798	.33	9.192294	13.87	10.807706	9
52	.187903	13.52	.994779	.32	.193124	13.83	.806876	8
53	.188712	13.48	.994759	.33	.193953	13.82	.806047	7
54	.189519	13.45	.994739	.32	.194780	13.78	.805220	6
55	.190325	13.43	.994720	.32	.195606	13.77	.804394	5
56	.191130	13.42	.994700	.33	.196430	13.73	.803570	4
57	.191933	13.38	.994680	.33	.197253	13.72	.802747	3
58	.192734	13.35	.994660	.33	.198074	13.68	.801926	2
59	.193534	13.33	.994640	.33	.198894	13.67	.801106	1
60'	9.194332	13.30	9.994620	.33	9.199713	13.65	10.800287	0
98°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	81°

9°	Sine.	D. 1°.	Cosine.	D. 1°.	Tang.	D. 1°.	Cotang. 170°	
0'	9.194332	13.28	9.994620	.33	9.199713	13.60	10.800287	60'
1	.195129	13.27	.994600	.33	.200529	13.60	.799471	59
2	.195925	13.23	.994580	.33	.201345	13.57	.798655	58
3	.196719	13.20	.994560	.33	.202159	13.53	.797841	57
4	.197511	13.18	.994540	.33	.202971	13.52	.797029	56
5	.198302	13.15	.994519	.33	.203782	13.50	.796218	55
6	.199091	13.13	.994499	.33	.204592	13.47	.795408	54
7	.199879	13.12	.994479	.33	.205400	13.45	.794600	53
8	.200666	13.08	.994459	.33	.206207	13.43	.793793	52
9	.201451	13.05	.994438	.33	.207013	13.40	.792987	51
10	.202234	13.05	.994418	.33	.207817	13.37	.792183	50
11	9.203017	13.00	9.994398	.35	9.208619	13.35	10.791381	49
12	.203797	13.00	.994377	.33	.209420	13.33	.790580	48
13	.204577	12.95	.994357	.35	.210220	13.30	.789780	47
14	.205354	12.95	.994336	.33	.211018	13.28	.788982	46
15	.206131	12.92	.994316	.35	.211815	13.27	.788185	45
16	.206906	12.88	.994295	.35	.212611	13.23	.787389	44
17	.207679	12.88	.994274	.33	.213405	13.22	.786595	43
18	.208452	12.83	.994254	.35	.214198	13.18	.785802	42
19	.209222	12.83	.994233	.35	.214989	13.18	.785011	41
20	.209992	12.80	.994212	.35	.215780	13.13	.784220	40
21	9.210760	12.77	9.994191	.33	9.216568	13.13	10.783432	39
22	.211526	12.75	.994171	.35	.217356	13.10	.782644	38
23	.212291	12.73	.994150	.35	.218142	13.07	.781858	37
24	.213055	12.72	.994129	.35	.218926	13.07	.781074	36
25	.213818	12.68	.994108	.35	.219710	13.03	.780290	35
26	.214579	12.65	.994087	.35	.220492	13.00	.779508	34
27	.215338	12.65	.994066	.35	.221272	13.00	.778728	33
28	.216097	12.62	.994045	.35	.222052	12.97	.777948	32
29	.216854	12.58	.994024	.35	.222830	12.95	.777170	31
30	.217609	12.57	.994003	.35	.223607	12.92	.776393	30
31	9.218363	12.55	9.993982	.37	9.224382	12.90	10.775618	29
32	.219116	12.53	.993960	.35	.225156	12.88	.774844	28
33	.219868	12.50	.993939	.35	.225929	12.85	.774071	27
34	.220618	12.48	.993918	.35	.226700	12.85	.773300	26
35	.221367	12.47	.993897	.35	.227471	12.80	.772529	25
36	.222115	12.43	.993875	.35	.228239	12.80	.771761	24
37	.222861	12.42	.993854	.37	.229007	12.77	.770993	23
38	.223606	12.38	.993832	.35	.229773	12.77	.770227	22
39	.224349	12.38	.993811	.37	.230539	12.72	.769461	21
40	.225092	12.35	.993789	.35	.231302	12.72	.768698	20
41	9.225833	12.33	9.993768	.37	9.232065	12.68	10.767935	19
42	.226573	12.30	.993746	.35	.232826	12.67	.767174	18
43	.227311	12.28	.993725	.37	.233586	12.65	.766414	17
44	.228048	12.27	.993703	.37	.234345	12.63	.765655	16
45	.228784	12.23	.993681	.35	.235103	12.60	.764897	15
46	.229518	12.23	.993660	.37	.235859	12.58	.764141	14
47	.230252	12.20	.993638	.37	.236614	12.57	.763386	13
48	.230984	12.18	.993616	.37	.237368	12.53	.762632	12
49	.231715	12.15	.993594	.37	.238120	12.53	.761880	11
50	.232444	12.13	.993572	.37	.238872	12.50	.761128	10
51	9.233172	12.12	9.993550	.37	9.239622	12.48	10.760378	9
52	.233899	12.10	.993528	.37	.240371	12.45	.759629	8
53	.234625	12.07	.993506	.37	.241118	12.45	.758882	7
54	.235349	12.07	.993484	.37	.241865	12.42	.758135	6
55	.236073	12.03	.993462	.37	.242610	12.40	.757390	5
56	.236795	12.00	.993440	.37	.243354	12.38	.756646	4
57	.237515	12.00	.993418	.37	.244097	12.37	.755903	3
58	.238235	11.97	.993396	.37	.244839	12.33	.755161	2
59	.238953	11.95	.993374	.38	.245579	12.33	.754421	1
60'	9.239670		9.993351		9.246319		10.753681	0'
99°	Cosine.	D. 1°.	Sine.	D. 1°.	Cotang.	D. 1°.	Tang.	80°

10°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang. 169°	
0'	9.239670	11.93	9.993351	.37	9.246319	12.30	10.753681	60'
1	.240386	11.92	.993329	.37	.247057	12.28	.752943	59
2	.241101	11.88	.993307	.38	.247794	12.27	.752206	58
3	.241814	11.87	.993284	.37	.248530	12.23	.751470	57
4	.242526	11.85	.993262	.37	.249264	12.23	.750736	56
5	.243237	11.85	.993240	.37	.249998	12.20	.750002	55
6	.243947	11.83	.993217	.38	.250730	12.20	.749270	54
7	.244656	11.82	.993195	.37	.251461	12.18	.748539	53
8	.245363	11.78	.993172	.38	.252191	12.17	.747809	52
9	.246069	11.77	.993149	.38	.252920	12.15	.747080	51
10	.246775	11.77	.993127	.37	.253648	12.13	.746352	50
		11.72		.38		12.10		
11	9.247478	11.72	9.993104	.38	9.254374	12.10	10.745626	49
12	.248181	11.70	.993081	.37	.255100	12.07	.744900	48
13	.248883	11.67	.993059	.38	.255824	12.05	.744176	47
14	.249583	11.65	.993036	.38	.256547	12.03	.743453	46
15	.250282	11.63	.993013	.38	.257269	12.02	.742731	45
16	.250980	11.62	.992990	.38	.257990	12.00	.742010	44
17	.251677	11.60	.992967	.38	.258710	11.98	.741290	43
18	.252373	11.57	.992944	.38	.259429	11.95	.740571	42
19	.253067	11.57	.992921	.38	.260146	11.95	.739854	41
20	.253761	11.53	.992898	.38	.260863	11.92	.739137	40
				.38				
21	9.254453	11.52	9.992875	.38	9.261578	11.90	10.738422	39
22	.255144	11.50	.992852	.38	.262292	11.88	.737708	38
23	.255834	11.48	.992829	.38	.263005	11.87	.736995	37
24	.256523	11.47	.992806	.38	.263717	11.85	.736283	36
25	.257211	11.45	.992783	.40	.264428	11.83	.735572	35
26	.257898	11.42	.992759	.40	.265138	11.83	.734862	34
27	.258583	11.42	.992736	.38	.265847	11.82	.734153	33
28	.259268	11.42	.992713	.38	.266555	11.80	.733445	32
29	.259951	11.38	.992690	.38	.267261	11.77	.732739	31
30	.260633	11.37	.992666	.40	.267967	11.77	.732033	30
		11.35		.38		11.73		
31	9.261314	11.33	9.992643	.40	9.268671	11.73	10.731329	29
32	.261994	11.32	.992619	.40	.269375	11.73	.730625	28
33	.262673	11.32	.992596	.38	.270077	11.70	.729923	27
34	.263351	11.30	.992572	.40	.270779	11.70	.729221	26
35	.264027	11.27	.992549	.38	.271479	11.67	.728521	25
36	.264703	11.27	.992525	.40	.272178	11.65	.727822	24
37	.265377	11.23	.992501	.40	.272876	11.63	.727124	23
38	.266051	11.23	.992478	.38	.273573	11.62	.726427	22
39	.266723	11.20	.992454	.40	.274269	11.60	.725731	21
40	.267395	11.20	.992430	.40	.274964	11.58	.725036	20
		11.17		.40		11.57		
41	9.268065	11.15	9.992406	.40	9.275658	11.55	10.724342	19
42	.268734	11.13	.992382	.40	.276351	11.55	.723649	18
43	.269402	11.13	.992359	.38	.277043	11.53	.722957	17
44	.270069	11.12	.992335	.40	.277734	11.52	.722266	16
45	.270735	11.10	.992311	.40	.278424	11.50	.721576	15
46	.271400	11.08	.992287	.40	.279113	11.48	.720887	14
47	.272064	11.07	.992263	.40	.279801	11.47	.720199	13
48	.272726	11.03	.992239	.40	.280488	11.45	.719512	12
49	.273388	11.03	.992214	.42	.281174	11.43	.718826	11
50	.274049	11.02	.992190	.40	.281858	11.40	.718142	10
		10.98		.40		11.40		
51	9.274708	10.98	9.992166	.40	9.282542	11.38	10.717458	9
52	.275367	10.97	.992142	.40	.283225	11.37	.716775	8
53	.276025	10.93	.992118	.42	.283907	11.35	.716093	7
54	.276681	10.93	.992093	.40	.284588	11.33	.715412	6
55	.277337	10.90	.992069	.42	.285268	11.33	.714732	5
56	.277991	10.90	.992044	.42	.285947	11.32	.714053	4
57	.278645	10.87	.992020	.40	.286624	11.28	.713376	3
58	.279297	10.85	.991996	.42	.287301	11.28	.712699	2
59	.279948	10.85	.991971	.42	.287977	11.27	.712023	1
60'	9.280599	10.85	9.991947	.40	9.288652	11.25	10.711348	0'
100° Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	79°	

11°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang. 168°	
0'	9.280599	10.82	9.991947	.42	9.288652	11.23	10.711348	60'
1	.281248	10.82	.991922	.42	.289326	11.22	.710674	59
2	.281897	10.78	.991897	.40	.289999	11.20	.710001	58
3	.282544	10.77	.991873	.42	.290671	11.18	.709329	57
4	.283190	10.77	.991848	.42	.291342	11.18	.708658	56
5	.283836	10.73	.991823	.40	.292013	11.15	.707987	55
6	.284480	10.73	.991799	.42	.292682	11.13	.707318	54
7	.285124	10.70	.991774	.42	.293350	11.12	.706650	53
8	.285766	10.70	.991749	.42	.294017	11.12	.705983	52
9	.286408	10.67	.991724	.42	.294684	11.08	.705316	51
10	.287048	10.67	.991699	.42	.295349	11.07	.704651	50
11	9.287688	10.63	9.991674	.42	9.296013	11.07	10.703987	49
12	.288326	10.63	.991649	.42	.296677	11.03	.703323	48
13	.288964	10.60	.991624	.42	.297339	11.03	.702661	47
14	.289600	10.60	.991599	.42	.298001	11.02	.701999	46
15	.290236	10.57	.991574	.42	.298662	11.00	.701338	45
16	.290870	10.57	.991549	.42	.299322	10.97	.700678	44
17	.291504	10.55	.991524	.43	.299980	10.97	.700020	43
18	.292137	10.52	.991498	.42	.300638	10.95	.699362	42
19	.292768	10.52	.991473	.42	.301295	10.93	.698705	41
20	.293399	10.50	.991448	.43	.301951	10.93	.698049	40
21	9.294029	10.48	9.991422	.42	9.302607	10.90	10.697393	39
22	.294658	10.47	.991397	.42	.303261	10.88	.696739	38
23	.295286	10.45	.991372	.43	.303914	10.88	.696086	37
24	.295913	10.43	.991346	.42	.304567	10.85	.695433	36
25	.296539	10.42	.991321	.43	.305218	10.85	.694782	35
26	.297164	10.40	.991295	.42	.305869	10.83	.694131	34
27	.297788	10.40	.991270	.43	.306519	10.82	.693481	33
28	.298412	10.37	.991244	.43	.307168	10.82	.692832	32
29	.299034	10.35	.991218	.42	.307816	10.80	.692184	31
30	.299655	10.35	.991193	.43	.308463	10.78	.691537	30
31	9.300276	10.32	9.991167	.43	9.309109	10.75	10.690891	29
32	.300895	10.32	.991141	.43	.309754	10.75	.690246	28
33	.301514	10.30	.991115	.42	.310399	10.72	.689601	27
34	.302132	10.27	.991090	.43	.311042	10.72	.688958	26
35	.302748	10.27	.991064	.43	.311685	10.70	.688315	25
36	.303364	10.25	.991038	.43	.312327	10.68	.687673	24
37	.303979	10.23	.991012	.43	.312968	10.67	.687032	23
38	.304593	10.23	.990986	.43	.313608	10.65	.686392	22
39	.305207	10.20	.990960	.43	.314247	10.63	.685753	21
40	.305819	10.18	.990934	.43	.314885	10.63	.685115	20
41	9.306430	10.18	9.990908	.43	9.315523	10.60	10.684477	19
42	.307041	10.15	.990882	.45	.316159	10.60	.683841	18
43	.307650	10.15	.990855	.43	.316795	10.58	.683205	17
44	.308259	10.13	.990829	.43	.317430	10.57	.682570	16
45	.308867	10.12	.990803	.43	.318064	10.55	.681936	15
46	.309474	10.10	.990777	.45	.318697	10.55	.681303	14
47	.310080	10.08	.990750	.43	.319330	10.52	.680670	13
48	.310685	10.07	.990724	.45	.319961	10.52	.680039	12
49	.311289	10.07	.990697	.43	.320592	10.50	.679408	11
50	.311893	10.03	.990671	.43	.321222	10.48	.678778	10
51	9.312495	10.03	9.990645	.45	9.321851	10.47	10.678149	9
52	.313097	10.02	.990618	.45	.322479	10.45	.677521	8
53	.313698	9.98	.990591	.43	.323106	10.45	.676894	7
54	.314297	10.00	.990565	.45	.323733	10.42	.676267	6
55	.314897	9.97	.990538	.45	.324358	10.42	.675642	5
56	.315495	9.95	.990511	.43	.324983	10.40	.675017	4
57	.316092	9.95	.990485	.45	.325607	10.40	.674393	3
58	.316689	9.92	.990458	.45	.326231	10.37	.673769	2
59	.317284	9.92	.990431	.45	.326853	10.37	.673147	1
60'	9.317879		9.990404		9.327475		10.672525	0'
101°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	78°

12°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 167°	
0'	9.317879	9.90	9.990404	.43	9.327475	10.33	10.672525	60'
1	.318473	9.88	.990378	.45	.328095	10.33	.671905	59
2	.319066	9.87	.990351	.45	.328715	10.32	.671285	58
3	.319658	9.85	.990324	.45	.329334	10.32	.670666	57
4	.320249	9.85	.990297	.45	.329953	10.32	.670047	56
5	.320840	9.83	.990270	.45	.330570	10.28	.669430	55
6	.321430	9.82	.990243	.47	.331187	10.28	.668813	54
7	.322019	9.80	.990215	.47	.331803	10.27	.668197	53
8	.322607	9.78	.990188	.45	.332418	10.25	.667582	52
9	.323194	9.77	.990161	.45	.333033	10.22	.666967	51
10	.323780	9.77	.990134	.45	.333646	10.22	.666354	50
11	9.324366	9.73	9.990107	.47	9.334259	10.20	10.665741	49
12	.324950	9.73	.990079	.47	.334871	10.18	.665129	48
13	.325534	9.72	.990052	.45	.335482	10.18	.664518	47
14	.326117	9.72	.990025	.45	.336093	10.15	.663907	46
15	.326700	9.68	.989997	.45	.336702	10.15	.663298	45
16	.327281	9.68	.989970	.45	.337311	10.13	.662689	44
17	.327862	9.67	.989942	.47	.337919	10.13	.662081	43
18	.328442	9.65	.989915	.45	.338527	10.10	.661473	42
19	.329021	9.63	.989887	.45	.339133	10.10	.660867	41
20	.329599	9.62	.989860	.47	.339739	10.08	.660261	40
21	9.330176	9.62	9.989832	.47	9.340344	10.07	10.659656	39
22	.330753	9.60	.989804	.45	.340948	10.07	.659052	38
23	.331329	9.57	.989777	.47	.341552	10.05	.658448	37
24	.331903	9.58	.989749	.47	.342155	10.03	.657845	36
25	.332478	9.55	.989721	.47	.342757	10.02	.657243	35
26	.333051	9.55	.989693	.47	.343358	10.00	.656642	34
27	.333624	9.52	.989665	.47	.343958	10.00	.656042	33
28	.334195	9.53	.989637	.45	.344558	9.98	.655442	32
29	.334767	9.50	.989610	.47	.345157	9.97	.654843	31
30	.335337	9.48	.989582	.48	.345755	9.97	.654245	30
31	9.335906	9.48	9.989553	.47	9.346353	9.93	10.653647	29
32	.336475	9.47	.989525	.47	.346949	9.93	.653051	28
33	.337043	9.45	.989497	.47	.347545	9.93	.652455	27
34	.337610	9.43	.989469	.47	.348141	9.90	.651859	26
35	.338176	9.43	.989441	.47	.348735	9.90	.651265	25
36	.338742	9.42	.989413	.47	.349329	9.88	.650671	24
37	.339307	9.40	.989385	.48	.349922	9.87	.650078	23
38	.339871	9.38	.989356	.47	.350514	9.87	.649486	22
39	.340434	9.37	.989328	.47	.351106	9.85	.648894	21
40	.340996	9.37	.989300	.48	.351697	9.83	.648303	20
41	9.341558	9.35	9.989271	.47	9.352287	9.82	10.647713	19
42	.342119	9.33	.989243	.48	.352876	9.82	.647124	18
43	.342679	9.33	.989214	.47	.353465	9.80	.646535	17
44	.343239	9.30	.989186	.48	.354053	9.78	.645947	16
45	.343797	9.30	.989157	.48	.354640	9.78	.645360	15
46	.344355	9.28	.989128	.48	.355227	9.77	.644773	14
47	.344912	9.28	.989100	.47	.355813	9.75	.644187	13
48	.345469	9.25	.989071	.48	.356398	9.73	.643602	12
49	.346024	9.25	.989042	.47	.356982	9.73	.643018	11
50	.346579	9.25	.989014	.48	.357566	9.72	.642434	10
51	9.347134	9.22	9.988985	.48	9.358149	9.70	10.641851	9
52	.347687	9.22	.988956	.48	.358731	9.70	.641269	8
53	.348240	9.20	.988927	.48	.359313	9.67	.640687	7
54	.348792	9.18	.988898	.48	.359893	9.68	.640107	6
55	.349343	9.17	.988869	.48	.360474	9.65	.639526	5
56	.349893	9.17	.988840	.48	.361053	9.65	.638947	4
57	.350443	9.15	.988811	.48	.361632	9.63	.638368	3
58	.350992	9.13	.988782	.48	.362210	9.62	.637790	2
59	.351540	9.13	.988753	.48	.362787	9.62	.637213	1
60'	9.352088		9.988724	.48	9.363364		10.636636	0'
102°	Cosine.	D. 1'.	Sine,	D. 1'.	Cotang.	D. 1'.	Tang.	77°

13°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	166°
0'	9.352088		9.988724		9.363364		10.636636	60
1	.352635	9.12	.988695	.48	.363940	9.60	.636060	59
2	.353181	9.10	.988666	.48	.364515	9.58	.635485	58
3	.353726	9.08	.988636	.50	.365090	9.58	.634910	57
4	.354271	9.08	.988607	.48	.365664	9.57	.634336	56
5	.354815	9.07	.988578	.48	.366237	9.55	.633763	55
6	.355358	9.05	.988548	.50	.366810	9.55	.633190	54
7	.355901	9.05	.988519	.48	.367382	9.53	.632618	53
8	.356443	9.03	.988489	.50	.367953	9.52	.632047	52
9	.356984	9.02	.988460	.48	.368524	9.52	.631476	51
10	.357524	9.00	.988430	.50	.369094	9.50	.630906	50
		9.00		.48		9.48		
11	9.358064	8.98	9.988401	.50	9.369663	9.48	10.630337	49
12	.358603	8.97	.988371	.48	.370232	9.45	.629768	48
13	.359141	8.95	.988342	.50	.370799	9.47	.629201	47
14	.359678	8.95	.988312	.50	.371367	9.43	.628633	46
15	.360215	8.95	.988282	.50	.371933	9.43	.628067	45
16	.360752	8.92	.988252	.50	.372499	9.43	.627501	44
17	.361287	8.92	.988223	.48	.373064	9.42	.626936	43
18	.361822	8.92	.988193	.50	.373629	9.42	.626371	42
19	.362356	8.90	.988163	.50	.374193	9.40	.625807	41
20	.362889	8.88	.988133	.50	.374756	9.38	.625244	40
		8.88		.50		9.38		
21	9.363422	8.87	9.988103	.50	9.375319	9.37	10.624681	39
22	.363954	8.85	.988073	.50	.375881	9.35	.624119	38
23	.364485	8.85	.988043	.50	.376442	9.35	.623558	37
24	.365016	8.83	.988013	.50	.377003	9.33	.622997	36
25	.365546	8.82	.987983	.50	.377563	9.33	.622437	35
26	.366075	8.82	.987953	.50	.378122	9.32	.621878	34
27	.366604	8.82	.987922	.52	.378681	9.32	.621319	33
28	.367131	8.78	.987892	.50	.379239	9.30	.620761	32
29	.367659	8.80	.987862	.50	.379797	9.30	.620203	31
30	.368185	8.77	.987832	.50	.380354	9.28	.619646	30
		8.77		.52		9.27		
31	9.368711	8.75	9.987801	.50	9.380910	9.27	10.619090	29
32	.369236	8.75	.987771	.50	.381466	9.27	.618534	28
33	.369761	8.75	.987740	.52	.382020	9.23	.617980	27
34	.370285	8.72	.987710	.50	.382575	9.25	.617425	26
35	.370808	8.72	.987679	.52	.383129	9.23	.616871	25
36	.371330	8.70	.987649	.50	.383682	9.22	.616318	24
37	.371852	8.70	.987618	.52	.384234	9.22	.615766	23
38	.372373	8.68	.987588	.50	.384786	9.20	.615214	22
39	.372894	8.68	.987557	.52	.385337	9.18	.614663	21
40	.373414	8.67	.987526	.52	.385888	9.18	.614112	20
		8.65		.50		9.17		
41	9.373933	8.65	9.987496	.52	9.386438	9.15	10.613562	19
42	.374452	8.65	.987465	.52	.386987	9.15	.613013	18
43	.374970	8.63	.987434	.52	.387536	9.15	.612464	17
44	.375487	8.62	.987403	.52	.388084	9.13	.611916	16
45	.376003	8.60	.987372	.52	.388631	9.12	.611369	15
46	.376519	8.60	.987341	.52	.389178	9.12	.610822	14
47	.377035	8.60	.987310	.52	.389724	9.10	.610276	13
48	.377549	8.57	.987279	.52	.390270	9.10	.609730	12
49	.378063	8.57	.987248	.52	.390815	9.08	.609185	11
50	.378577	8.57	.987217	.52	.391360	9.08	.608640	10
		8.53		.52		9.05		
51	9.379089	8.53	9.987186	.52	9.391903	9.07	10.608097	9
52	.379601	8.53	.987155	.52	.392447	9.07	.607553	8
53	.380113	8.53	.987124	.52	.392989	9.03	.607011	7
54	.380624	8.52	.987092	.53	.393531	9.03	.606469	6
55	.381134	8.50	.987061	.52	.394073	9.03	.605927	5
56	.381643	8.48	.987030	.52	.394614	9.02	.605386	4
57	.382152	8.48	.986998	.53	.395154	9.00	.604846	3
58	.382661	8.48	.986967	.52	.395694	9.00	.604306	2
59	.383168	8.45	.986936	.52	.396233	8.98	.603767	1
30'	9.383675	8.45	9.986904	.53	9.396771	8.97	10.603229	0'
103° Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	76°	

14°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	165°
0'	9.383675	8.45	9.986904	.52	9.396771	8.97	10.603229	60'
1	.384182	8.42	.986873	.53	.397309	8.95	.602691	59
2	.384687	8.42	.986841	.53	.397846	8.95	.602154	58
3	.385192	8.42	.986809	.52	.398383	8.93	.601617	57
4	.385697	8.40	.986778	.53	.398919	8.93	.601081	56
5	.386201	8.38	.986746	.53	.399455	8.93	.600545	55
6	.386704	8.38	.986714	.52	.399990	8.92	.600010	54
7	.387207	8.37	.986683	.53	.400524	8.90	.599476	53
8	.387709	8.35	.986651	.53	.401058	8.90	.598942	52
9	.388210	8.35	.986619	.53	.401591	8.88	.598409	51
10	.388711	8.33	.986587	.53	.402124	8.88	.597876	50
11	9.389211	8.33	9.986555	.53	9.402656	8.85	10.597344	49
12	.389711	8.32	.986523	.53	.403187	8.85	.596813	48
13	.390210	8.30	.986491	.53	.403718	8.85	.596282	47
14	.390708	8.30	.986459	.53	.404249	8.82	.595751	46
15	.391206	8.28	.986427	.53	.404778	8.83	.595222	45
16	.391703	8.27	.986395	.53	.405308	8.80	.594692	44
17	.392199	8.27	.986363	.53	.405836	8.80	.594164	43
18	.392695	8.27	.986331	.53	.406364	8.80	.593636	42
19	.393191	8.23	.986299	.55	.406892	8.78	.593108	41
20	.393685	8.23	.986266	.53	.407419	8.77	.592581	40
21	9.394179	8.23	9.986234	.53	9.407945	8.77	10.592055	39
22	.394673	8.22	.986202	.55	.408471	8.75	.591529	38
23	.395166	8.20	.986169	.53	.408996	8.75	.591004	37
24	.395658	8.20	.986137	.55	.409521	8.73	.590479	36
25	.396150	8.18	.986104	.53	.410045	8.73	.589955	35
26	.396641	8.18	.986072	.55	.410569	8.73	.589431	34
27	.397132	8.15	.986039	.55	.411092	8.72	.588908	33
28	.397621	8.17	.986007	.55	.411615	8.72	.588385	32
29	.398111	8.15	.985974	.53	.412137	8.70	.587863	31
30	.398600	8.13	.985942	.55	.412658	8.68	.587342	30
31	9.399088	8.12	9.985909	.55	9.413179	8.67	10.586821	29
32	.399575	8.12	.985876	.55	.413699	8.67	.586301	28
33	.400062	8.12	.985843	.55	.414219	8.65	.585781	27
34	.400549	8.10	.985811	.53	.414738	8.65	.585262	26
35	.401035	8.08	.985778	.55	.415257	8.63	.584743	25
36	.401520	8.08	.985745	.55	.415775	8.63	.584225	24
37	.402005	8.07	.985712	.55	.416293	8.62	.583707	23
38	.402489	8.05	.985679	.55	.416810	8.62	.583190	22
39	.402972	8.05	.985646	.55	.417326	8.60	.582674	21
40	.403455	8.05	.985613	.55	.417842	8.60	.582158	20
41	9.403938	8.03	9.985580	.55	9.418358	8.58	10.581642	19
42	.404420	8.02	.985547	.55	.418873	8.57	.581127	18
43	.404901	8.02	.985514	.55	.419387	8.57	.580613	17
44	.405382	8.00	.985480	.57	.419901	8.57	.580099	16
45	.405862	7.98	.985447	.55	.420415	8.53	.579585	15
46	.406341	7.98	.985414	.55	.420927	8.55	.579073	14
47	.406820	7.98	.985381	.57	.421440	8.53	.578560	13
48	.407299	7.97	.985347	.55	.421952	8.52	.578048	12
49	.407777	7.95	.985314	.57	.422463	8.52	.577537	11
50	.408254	7.95	.985280	.55	.422974	8.50	.577026	10
51	9.408731	7.93	9.985247	.57	9.423484	8.48	10.576516	9
52	.409207	7.93	.985213	.55	.423993	8.50	.576007	8
53	.409682	7.92	.985180	.57	.424503	8.47	.575497	7
54	.410157	7.92	.985146	.55	.425011	8.47	.574989	6
55	.410632	7.90	.985113	.57	.425519	8.47	.574481	5
56	.411106	7.88	.985079	.57	.426027	8.45	.573973	4
57	.411579	7.88	.985045	.57	.426534	8.45	.573466	3
58	.412052	7.87	.985011	.55	.427041	8.43	.572959	2
59	.412524	7.87	.984978	.55	.427547	8.42	.572453	1
60'	9.412996		9.984944	.57	9.423052		10.571948	0'
104°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	75°

15°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	164°
0'	9.412996	7.85	9.984944	.57	9.428052	8.43	10.571948	60
1	.413467	7.85	.984910	.57	.428558	8.40	.571442	59
2	.413938	7.83	.984876	.57	.429062	8.40	.570938	58
3	.414408	7.83	.984842	.57	.429566	8.40	.570434	57
4	.414878	7.82	.984808	.57	.430070	8.38	.569930	56
5	.415347	7.80	.984774	.57	.430573	8.38	.569427	55
6	.415815	7.80	.984740	.57	.431075	8.37	.568925	54
7	.416283	7.80	.984706	.57	.431577	8.37	.568423	53
8	.416751	7.80	.984672	.57	.432079	8.35	.567921	52
9	.417217	7.77	.984638	.57	.432580	8.35	.567420	51
10	.417684	7.77	.984603	.57	.433080	8.33	.566920	50
11	9.418150	7.75	9.984569	.57	9.433580	8.33	10.566420	49
12	.418615	7.73	.984535	.58	.434080	8.32	.565920	48
13	.419079	7.75	.984500	.57	.434579	8.32	.565421	47
14	.419544	7.72	.984466	.57	.435078	8.32	.564922	46
15	.420007	7.72	.984432	.57	.435576	8.30	.564424	45
16	.420470	7.72	.984397	.58	.436073	8.28	.563927	44
17	.420933	7.72	.984363	.57	.436570	8.28	.563430	43
18	.421395	7.70	.984328	.58	.437067	8.28	.562933	42
19	.421857	7.70	.984294	.57	.437563	8.27	.562437	41
20	.422318	7.68	.984259	.58	.438059	8.27	.561941	40
21	9.422778	7.67	9.984224	.57	9.438554	8.25	10.561446	39
22	.423238	7.67	.984190	.57	.439048	8.23	.560952	38
23	.423697	7.65	.984155	.58	.439543	8.25	.560457	37
24	.424156	7.65	.984120	.58	.440036	8.22	.559964	36
25	.424615	7.65	.984085	.58	.440529	8.22	.559471	35
26	.425073	7.63	.984050	.58	.441022	8.22	.558978	34
27	.425530	7.62	.984015	.58	.441514	8.20	.558486	33
28	.425987	7.62	.983981	.57	.442006	8.20	.557994	32
29	.426443	7.60	.983946	.58	.442497	8.18	.557503	31
30	.426899	7.60	.983911	.58	.442988	8.18	.557012	30
31	9.427354	7.58	9.983875	.60	9.443479	8.18	10.556521	29
32	.427809	7.58	.983840	.58	.443968	8.15	.556032	28
33	.428263	7.57	.983805	.58	.444458	8.17	.555542	27
34	.428717	7.57	.983770	.58	.444947	8.15	.555053	26
35	.429170	7.55	.983735	.58	.445435	8.13	.554565	25
36	.429623	7.55	.983700	.58	.445923	8.13	.554077	24
37	.430075	7.53	.983664	.60	.446411	8.13	.553589	23
38	.430527	7.53	.983629	.58	.446898	8.12	.553102	22
39	.430978	7.52	.983594	.58	.447384	8.10	.552616	21
40	.431429	7.52	.983558	.60	.447870	8.10	.552130	20
41	9.431879	7.50	9.983523	.58	9.448356	8.10	10.551644	19
42	.432329	7.50	.983487	.60	.448841	8.08	.551159	18
43	.432778	7.48	.983452	.58	.449326	8.08	.550674	17
44	.433226	7.47	.983416	.60	.449810	8.07	.550190	16
45	.433675	7.48	.983381	.58	.450294	8.07	.549706	15
46	.434122	7.45	.983345	.60	.450777	8.05	.549223	14
47	.434569	7.45	.983309	.60	.451260	8.05	.548740	13
48	.435016	7.45	.983273	.60	.451743	8.05	.548257	12
49	.435462	7.43	.983238	.58	.452225	8.03	.547775	11
50	.435908	7.43	.983202	.60	.452706	8.02	.547294	10
51	9.436353	7.42	9.983166	.60	9.453187	8.02	10.546813	9
52	.436798	7.42	.983130	.60	.453668	8.02	.546332	8
53	.437242	7.40	.983094	.60	.454148	8.00	.545852	7
54	.437686	7.40	.983058	.60	.454628	8.00	.545372	6
55	.438129	7.38	.983022	.60	.455107	7.98	.544893	5
56	.438572	7.38	.982986	.60	.455586	7.98	.544414	4
57	.439014	7.37	.982950	.60	.456064	7.97	.543936	3
58	.439456	7.37	.982914	.60	.456542	7.97	.543458	2
59	.439897	7.35	.982878	.60	.457019	7.95	.542981	1
60'	9.440338	7.35	9.982842		9.457496	7.95	10.542504	0'
105°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	74°

16°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang. 163°	
0'	9.440338	7.33	9.982842	.62	9.457496	7.95	10.542504	60'
1	.440778	7.33	.982805	.60	.457973	7.93	.542027	59
2	.441218	7.33	.982769	.60	.458449	7.93	.541551	58
3	.441658	7.33	.982733	.62	.458925	7.92	.541075	57
4	.442096	7.32	.982696	.60	.459400	7.92	.540600	56
5	.442535	7.30	.982660	.60	.459875	7.90	.540125	55
6	.442973	7.28	.982624	.62	.460349	7.90	.539651	54
7	.443410	7.28	.982587	.60	.460823	7.90	.539177	53
8	.443847	7.28	.982551	.62	.461297	7.88	.538703	52
9	.444284	7.27	.982514	.62	.461770	7.87	.538230	51
10	.444720	7.25	.982477	.60	.462242	7.88	.537758	50
11	9.445155	7.25	9.982441	.62	9.462715	7.85	10.537285	49
12	.445590	7.25	.982404	.62	.463186	7.87	.536814	48
13	.446025	7.23	.982367	.60	.463658	7.83	.536342	47
14	.446459	7.23	.982331	.62	.464128	7.85	.535872	46
15	.446893	7.22	.982294	.62	.464599	7.83	.535401	45
16	.447326	7.22	.982257	.62	.465069	7.83	.534931	44
17	.447759	7.20	.982220	.62	.465539	7.82	.534461	43
18	.448191	7.20	.982183	.62	.466008	7.82	.533992	42
19	.448623	7.18	.982146	.62	.466477	7.80	.533523	41
20	.449054	7.18	.982109	.62	.466945	7.80	.533055	40
21	9.449485	7.17	9.982072	.62	9.467413	7.78	10.532587	39
22	.449915	7.17	.982035	.62	.467880	7.78	.532120	38
23	.450345	7.17	.981998	.62	.468347	7.78	.531653	37
24	.450775	7.15	.981961	.62	.468814	7.77	.531186	36
25	.451204	7.13	.981924	.63	.469280	7.77	.530720	35
26	.451632	7.13	.981886	.62	.469746	7.75	.530254	34
27	.452060	7.13	.981849	.62	.470211	7.75	.529789	33
28	.452488	7.12	.981812	.63	.470676	7.75	.529324	32
29	.452915	7.12	.981774	.62	.471141	7.73	.528859	31
30	.453342	7.10	.981737	.62	.471605	7.73	.528395	30
31	9.453768	7.10	9.981700	.63	9.472069	7.72	10.527931	29
32	.454194	7.08	.981662	.62	.472532	7.72	.527468	28
33	.454619	7.08	.981625	.63	.472995	7.70	.527005	27
34	.455044	7.08	.981587	.63	.473457	7.70	.526543	26
35	.455469	7.07	.981549	.62	.473919	7.70	.526081	25
36	.455893	7.05	.981512	.62	.474381	7.68	.525619	24
37	.456316	7.05	.981474	.63	.474842	7.68	.525158	23
38	.456739	7.05	.981436	.62	.475303	7.67	.524697	22
39	.457162	7.03	.981399	.63	.475763	7.67	.524237	21
40	.457584	7.03	.981361	.63	.476223	7.67	.523777	20
41	9.458006	7.02	9.981323	.63	9.476683	7.65	10.523317	19
42	.458427	7.02	.981285	.63	.477142	7.65	.522858	18
43	.458848	7.00	.981247	.63	.477601	7.63	.522399	17
44	.459268	7.00	.981209	.63	.478059	7.63	.521941	16
45	.459688	7.00	.981171	.63	.478517	7.63	.521483	15
46	.460108	6.98	.981133	.63	.478975	7.62	.521025	14
47	.460527	6.98	.981095	.63	.479432	7.62	.520568	13
48	.460946	6.97	.981057	.63	.479889	7.60	.520111	12
49	.461364	6.97	.981019	.63	.480345	7.60	.519655	11
50	.461782	6.95	.980981	.65	.480801	7.60	.519199	10
51	9.462199	6.95	9.980942	.63	9.481257	7.58	10.518743	9
52	.462616	6.93	.980904	.63	.481712	7.58	.518288	8
53	.463032	6.93	.980866	.65	.482167	7.57	.517833	7
54	.463448	6.93	.980827	.63	.482621	7.57	.517379	6
55	.463864	6.92	.980789	.65	.483075	7.57	.516925	5
56	.464279	6.92	.980750	.63	.483529	7.55	.516471	4
57	.464694	6.90	.980712	.65	.483982	7.55	.516018	3
58	.465108	6.90	.980673	.63	.484435	7.53	.515565	2
59	.465522	6.88	.980635	.65	.484887	7.53	.515113	1
60'	9.465935		9.980596		9.485339		10.514661	0'
106°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	73°

17°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 162°	
0'	9.465935	6.88	9.980596	.63	9.485339	7.53	10.514661	60'
1	.466348	6.88	.980558	.65	.485791	7.52	.514209	59
2	.466761	6.87	.980519	.65	.486242	7.52	.513758	58
3	.467173	6.87	.980480	.65	.486693	7.50	.513307	57
4	.467585	6.85	.980442	.65	.487143	7.50	.512857	56
5	.467996	6.85	.980403	.65	.487593	7.50	.512407	55
6	.468407	6.83	.980364	.65	.488043	7.48	.511957	54
7	.468817	6.83	.980325	.65	.488492	7.48	.511508	53
8	.469227	6.83	.980286	.65	.488941	7.48	.511059	52
9	.469637	6.82	.980247	.65	.489390	7.47	.510610	51
10	.470046	6.82	.980208	.65	.489838	7.47	.510162	50
11	9.470455	6.80	9.980169	.65	9.490286	7.45	10.509714	49
12	.470863	6.80	.980130	.65	.490733	7.45	.509267	48
13	.471271	6.80	.980091	.65	.491180	7.45	.508820	47
14	.471679	6.78	.980052	.67	.491627	7.43	.508373	46
15	.472086	6.77	.980012	.65	.492073	7.43	.507927	45
16	.472492	6.77	.979973	.65	.492519	7.43	.507481	44
17	.472898	6.77	.979934	.65	.492965	7.43	.507035	43
18	.473304	6.77	.979895	.67	.493410	7.40	.506590	42
19	.473710	6.75	.979855	.65	.493854	7.42	.506146	41
20	.474115	6.73	.979816	.67	.494299	7.40	.505701	40
21	9.474519	6.73	9.979776	.65	9.494743	7.38	10.505257	39
22	.474923	6.73	.979737	.67	.495186	7.38	.504814	38
23	.475327	6.72	.979697	.65	.495630	7.38	.504370	37
24	.475730	6.72	.979658	.67	.496073	7.37	.503927	36
25	.476133	6.72	.979618	.67	.496515	7.37	.503485	35
26	.476536	6.70	.979579	.65	.496957	7.37	.503043	34
27	.476938	6.70	.979539	.67	.497399	7.37	.502601	33
28	.477340	6.68	.979499	.67	.497841	7.35	.502159	32
29	.477741	6.68	.979459	.65	.498282	7.33	.501718	31
30	.478142	6.67	.979420	.67	.498722	7.35	.501278	30
31	9.478542	6.67	9.979380	.67	9.499163	7.33	10.500837	29
32	.478942	6.67	.979340	.67	.499603	7.32	.500397	28
33	.479342	6.65	.979300	.67	.500042	7.32	.499958	27
34	.479741	6.65	.979260	.67	.500481	7.32	.499519	26
35	.480140	6.65	.979220	.67	.500920	7.32	.499080	25
36	.480539	6.63	.979180	.67	.501359	7.30	.498641	24
37	.480937	6.62	.979140	.67	.501797	7.30	.498203	23
38	.481334	6.62	.979100	.68	.502235	7.28	.497765	22
39	.481731	6.62	.979059	.67	.502672	7.28	.497328	21
40	.482128	6.62	.979019	.67	.503109	7.28	.496891	20
41	9.482525	6.60	9.978979	.67	9.503546	7.27	10.496454	19
42	.482921	6.58	.978939	.68	.503982	7.27	.496018	18
43	.483316	6.60	.978898	.67	.504418	7.27	.495582	17
44	.483712	6.58	.978858	.67	.504854	7.25	.495146	16
45	.484107	6.57	.978817	.67	.505289	7.25	.494711	15
46	.484501	6.57	.978777	.67	.505724	7.25	.494276	14
47	.484895	6.57	.978737	.67	.506159	7.23	.493841	13
48	.485289	6.55	.978696	.68	.506593	7.23	.493407	12
49	.485682	6.55	.978655	.67	.507027	7.22	.492973	11
50	.486075	6.53	.978615	.68	.507460	7.22	.492540	10
51	9.486467	6.55	9.978574	.68	9.507893	7.22	10.492107	9
52	.486860	6.52	.978533	.67	.508326	7.22	.491674	8
53	.487251	6.53	.978493	.68	.508759	7.20	.491241	7
54	.487643	6.52	.978452	.68	.509191	7.18	.490809	6
55	.488034	6.50	.978411	.68	.509622	7.18	.490378	5
56	.488424	6.50	.978370	.68	.510054	7.18	.489946	4
57	.488814	6.50	.978329	.68	.510485	7.18	.489515	3
58	.489204	6.48	.978288	.68	.510916	7.17	.489084	2
59	.489593	6.48	.978247	.68	.511346	7.17	.488654	1
60'	9.489982		9.978206		9.511776		10.488224	0'
107°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	72°

18°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 161°	
0'	9.489982		9.978206		9.511776		10.488224	60
1	.490371	6.48	.978165	.68	.512206	7.17	.487794	59
2	.490759	6.47	.978124	.68	.512635	7.15	.487365	58
3	.491147	6.47	.978083	.68	.513064	7.15	.486936	57
4	.491535	6.47	.978042	.68	.513493	7.15	.486507	56
5	.491922	6.45	.978001	.68	.513921	7.13	.486079	55
6	.492308	6.43	.977959	.70	.514349	7.13	.485651	54
7	.492695	6.45	.977918	.68	.514777	7.13	.485223	53
8	.493081	6.43	.977877	.68	.515204	7.12	.484796	52
9	.493466	6.42	.977835	.70	.515631	7.12	.484369	51
10	.493851	6.42	.977794	.68	.516057	7.10	.483943	50
				.70		7.12		
11	9.494236	6.42	9.977752		9.516484		10.483516	49
12	.494621	6.40	.977711	.68	.516910	7.10	.483090	48
13	.495005	6.40	.977669	.70	.517335	7.08	.482665	47
14	.495388	6.38	.977628	.68	.517761	7.10	.482239	46
15	.495772	6.40	.977586	.70	.518186	7.08	.481814	45
16	.496154	6.37	.977544	.70	.518610	7.07	.481390	44
17	.496537	6.38	.977503	.68	.519034	7.07	.480966	43
18	.496919	6.37	.977461	.70	.519458	7.07	.480542	42
19	.497301	6.37	.977419	.70	.519882	7.07	.480118	41
20	.497682	6.35	.977377	.70	.520305	7.05	.479695	40
		6.37		.70		7.05		
21	9.498064	6.33	9.977335		9.520728		10.479272	39
22	.498444	6.33	.977293	.70	.521151	7.05	.478849	38
23	.498825	6.35	.977251	.70	.521573	7.03	.478427	37
24	.499204	6.32	.977209	.70	.521995	7.03	.478005	36
25	.499584	6.33	.977167	.70	.522417	7.03	.477583	35
26	.499963	6.32	.977125	.70	.522838	7.02	.477162	34
27	.500342	6.32	.977083	.70	.523259	7.02	.476741	33
28	.500721	6.32	.977041	.70	.523680	7.02	.476320	32
29	.501099	6.30	.976999	.70	.524100	7.00	.475900	31
30	.501476	6.28	.976957	.70	.524520	7.00	.475480	30
		6.30		.72		7.00		
31	9.501854	6.28	9.976914		9.524940		10.475060	29
32	.502231	6.27	.976872	.70	.525359	6.98	.474641	28
33	.502607	6.27	.976830	.70	.525778	6.98	.474222	27
34	.502984	6.28	.976787	.72	.526197	6.98	.473803	26
35	.503360	6.27	.976745	.70	.526615	6.97	.473385	25
36	.503735	6.25	.976702	.72	.527033	6.97	.472967	24
37	.504110	6.25	.976660	.70	.527451	6.97	.472549	23
38	.504485	6.25	.976617	.72	.527868	6.95	.472132	22
39	.504860	6.25	.976574	.72	.528285	6.95	.471715	21
40	.505234	6.23	.976532	.70	.528702	6.95	.471298	20
		6.23		.72		6.95		
41	9.505608	6.22	9.976489		9.529119		10.470881	19
42	.505981	6.22	.976446	.72	.529535	6.93	.470465	18
43	.506354	6.22	.976404	.70	.529951	6.93	.470049	17
44	.506727	6.22	.976361	.72	.530366	6.92	.469634	16
45	.507099	6.20	.976318	.72	.530781	6.92	.469219	15
46	.507471	6.20	.976275	.72	.531196	6.92	.468804	14
47	.507843	6.20	.976232	.72	.531611	6.92	.468389	13
48	.508214	6.18	.976189	.72	.532025	6.90	.467975	12
49	.508585	6.18	.976146	.72	.532439	6.90	.467561	11
50	.508956	6.18	.976103	.72	.532853	6.90	.467147	10
		6.17		.72		6.88		
51	9.509326	6.17	9.976060		9.533266		10.466734	9
52	.509696	6.15	.976017	.72	.533679	6.88	.466321	8
53	.510065	6.15	.975974	.72	.534092	6.88	.465908	7
54	.510434	6.15	.975930	.73	.534504	6.87	.465496	6
55	.510803	6.15	.975887	.72	.534916	6.87	.465084	5
56	.511172	6.15	.975844	.72	.535328	6.87	.464672	4
57	.511540	6.13	.975800	.73	.535739	6.85	.464261	3
58	.511907	6.12	.975757	.72	.536150	6.85	.463850	2
59	.512275	6.13	.975714	.72	.536561	6.85	.463439	1
60'	9.512642	6.12	9.975670		9.536972		10.463028	0'
				.73		6.85		
108°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	71°

19°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	160°
0'	9.512642		9.975670		9.536972		10.463028	60'
1	.513009	6.12	.975627	.72	.537382	6.83	.462618	59
2	.513375	6.10	.975583	.73	.537792	6.83	.462208	58
3	.513741	6.10	.975539	.73	.538202	6.83	.461798	57
4	.514107	6.10	.975496	.72	.538611	6.82	.461389	56
5	.514472	6.08	.975452	.73	.539020	6.82	.460980	55
6	.514837	6.08	.975408	.73	.539429	6.82	.460571	54
7	.515202	6.08	.975365	.72	.539837	6.80	.460163	53
8	.515566	6.07	.975321	.73	.540245	6.80	.459755	52
9	.515930	6.07	.975277	.73	.540653	6.80	.459347	51
10	.516294	6.07	.975233	.73	.541061	6.80	.458939	50
		6.05		.73		6.78		
11	9.516657	6.05	9.975189	.73	9.541468	6.78	10.458532	49
12	.517020	6.03	.975145	.73	.541875	6.78	.458125	48
13	.517382	6.03	.975101	.73	.542281	6.77	.457719	47
14	.517745	6.05	.975057	.73	.542688	6.78	.457312	46
15	.518107	6.03	.975013	.73	.543094	6.77	.456906	45
16	.518468	6.02	.974969	.73	.543499	6.75	.456501	44
17	.518829	6.02	.974925	.73	.543905	6.77	.456095	43
18	.519190	6.02	.974880	.75	.544310	6.75	.455690	42
19	.519551	6.02	.974836	.73	.544715	6.75	.455285	41
20	.519911	6.00	.974792	.73	.545119	6.73	.454881	40
		6.00		.73		6.75		
21	9.520271	6.00	9.974748	.75	9.545524	6.73	10.454476	39
22	.520631	5.98	.974703	.73	.545928	6.72	.454072	38
23	.520990	5.98	.974659	.73	.546331	6.72	.453669	37
24	.521349	5.98	.974614	.75	.546735	6.73	.453265	36
25	.521707	5.97	.974570	.73	.547138	6.72	.452862	35
26	.522066	5.98	.974525	.75	.547540	6.70	.452460	34
27	.522424	5.97	.974481	.73	.547943	6.72	.452057	33
28	.522781	5.95	.974436	.75	.548345	6.70	.451655	32
29	.523138	5.95	.974391	.75	.548747	6.70	.451253	31
30	.523495	5.95	.974347	.73	.549149	6.70	.450851	30
		5.95		.75		6.68		
31	9.523852	5.93	9.974302	.75	9.549550	6.68	10.450450	29
32	.524208	5.93	.974257	.75	.549951	6.68	.450049	28
33	.524564	5.93	.974212	.75	.550352	6.68	.449648	27
34	.524920	5.93	.974167	.75	.550752	6.67	.449248	26
35	.525275	5.92	.974122	.75	.551153	6.68	.448847	25
36	.525630	5.92	.974077	.75	.551552	6.65	.448448	24
37	.525984	5.90	.974032	.75	.551952	6.67	.448048	23
38	.526339	5.92	.973987	.75	.552351	6.65	.447649	22
39	.526693	5.90	.973942	.75	.552750	6.65	.447250	21
40	.527046	5.88	.973897	.75	.553149	6.65	.446851	20
		5.90		.75		6.65		
41	9.527400	5.88	9.973852	.75	9.553548	6.63	10.446452	19
42	.527753	5.87	.973807	.75	.553946	6.63	.446054	18
43	.528105	5.87	.973761	.77	.554344	6.63	.445656	17
44	.528458	5.88	.973716	.75	.554741	6.62	.445259	16
45	.528810	5.87	.973671	.75	.555139	6.63	.444861	15
46	.529161	5.85	.973625	.77	.555536	6.62	.444464	14
47	.529513	5.87	.973580	.75	.555933	6.62	.444067	13
48	.529864	5.85	.973535	.75	.556329	6.60	.443671	12
49	.530215	5.85	.973489	.77	.556725	6.60	.443275	11
50	.530565	5.83	.973444	.75	.557121	6.60	.442879	10
		5.83		.77		6.60		
51	9.530915	5.82	9.973398	.77	9.557517	6.60	10.442483	9
52	.531265	5.82	.973352	.77	.557913	6.60	.442087	8
53	.531614	5.82	.973307	.75	.558308	6.58	.441692	7
54	.531963	5.82	.973261	.77	.558703	6.58	.441297	6
55	.532312	5.82	.973215	.77	.559097	6.57	.440903	5
56	.532661	5.82	.973169	.77	.559491	6.57	.440509	4
57	.533009	5.80	.973124	.75	.559885	6.57	.440115	3
58	.533357	5.80	.973078	.77	.560279	6.57	.439721	2
59	.533704	5.78	.973032	.77	.560673	6.57	.439327	1
60'	9.534052	5.80	9.972986	.77	9.561066	6.55	10.438934	0'

109°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	70°
------	---------	--------	-------	--------	---------	--------	-------	-----

20°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	159°
0'	9.534052	5.78	9.972986	.77	9.561066	6.55	10.438934	60'
1	.534399	5.77	.972940	.77	.561459	6.53	.438541	59
2	.534745	5.78	.972894	.77	.561851	6.55	.438149	58
3	.535092	5.77	.972848	.77	.562244	6.53	.437756	57
4	.535438	5.75	.972802	.78	.562636	6.53	.437364	56
5	.535783	5.77	.972755	.77	.563028	6.52	.436972	55
6	.536129	5.75	.972709	.77	.563419	6.53	.436581	54
7	.536474	5.73	.972663	.77	.563811	6.52	.436189	53
8	.536818	5.75	.972617	.78	.564202	6.52	.435798	52
9	.537163	5.73	.972570	.77	.564593	6.50	.435407	51
10	.537507	5.73	.972524	.77	.564983	6.50	.435017	50
11	9.537851	5.72	9.972478	.78	9.565373	6.50	10.434627	49
12	.538194	5.73	.972431	.77	.565763	6.50	.434237	48
13	.538538	5.70	.972385	.78	.566152	6.48	.433847	47
14	.538880	5.72	.972338	.78	.566542	6.50	.433458	46
15	.539223	5.70	.972291	.77	.566932	6.47	.433068	45
16	.539565	5.70	.972245	.78	.567320	6.48	.432680	44
17	.539907	5.68	.972198	.78	.567709	6.48	.432291	43
18	.540249	5.68	.972151	.77	.568098	6.47	.431902	42
19	.540590	5.68	.972105	.78	.568486	6.45	.431514	41
20	.540931	5.68	.972058	.78	.568873	6.47	.431127	40
21	9.541272	5.68	9.972011	.78	9.569261	6.45	10.430739	39
22	.541613	5.67	.971964	.78	.569648	6.45	.430352	38
23	.541953	5.67	.971917	.78	.570035	6.45	.429965	37
24	.542293	5.65	.971870	.78	.570422	6.45	.429578	36
25	.542632	5.65	.971823	.78	.570809	6.43	.429191	35
26	.542971	5.65	.971776	.78	.571195	6.43	.428805	34
27	.543310	5.65	.971729	.78	.571581	6.43	.428419	33
28	.543649	5.63	.971682	.78	.571967	6.42	.428033	32
29	.543987	5.63	.971635	.78	.572352	6.43	.427648	31
30	.544325	5.63	.971588	.80	.572738	6.42	.427262	30
31	9.544663	5.62	9.971540	.78	9.573123	6.40	10.426877	29
32	.545000	5.63	.971493	.78	.573507	6.42	.426493	28
33	.545338	5.60	.971446	.80	.573892	6.40	.426108	27
34	.545674	5.62	.971398	.78	.574276	6.40	.425724	26
35	.546011	5.60	.971351	.80	.574660	6.40	.425340	25
36	.546347	5.60	.971303	.78	.575044	6.38	.424956	24
37	.546683	5.60	.971256	.80	.575427	6.38	.424573	23
38	.547019	5.58	.971208	.78	.575810	6.38	.424190	22
39	.547354	5.58	.971161	.80	.576193	6.38	.423807	21
40	.547689	5.58	.971113	.78	.576576	6.38	.423424	20
41	9.548024	5.58	9.971066	.80	9.576959	6.37	10.423041	19
42	.548359	5.57	.971018	.80	.577341	6.37	.422659	18
43	.548693	5.57	.970970	.80	.577723	6.35	.422277	17
44	.549027	5.55	.970922	.80	.578104	6.37	.421896	16
45	.549360	5.55	.970874	.78	.578486	6.35	.421514	15
46	.549693	5.55	.970827	.80	.578867	6.35	.421133	14
47	.550026	5.55	.970779	.80	.579248	6.35	.420752	13
48	.550359	5.55	.970731	.80	.579629	6.33	.420371	12
49	.550692	5.53	.970683	.80	.580009	6.33	.419991	11
50	.551024	5.53	.970635	.82	.580389	6.33	.419611	10
51	9.551356	5.52	9.970586	.80	9.580769	6.33	10.419231	9
52	.551687	5.52	.970538	.80	.581149	6.32	.418851	8
53	.552018	5.52	.970490	.80	.581528	6.32	.418472	7
54	.552349	5.52	.970442	.80	.581907	6.32	.418093	6
55	.552680	5.50	.970394	.82	.582286	6.32	.417714	5
56	.553010	5.52	.970345	.80	.582665	6.32	.417335	4
57	.553341	5.48	.970297	.80	.583044	6.30	.416956	3
58	.553670	5.50	.970249	.82	.583422	6.30	.416578	2
59	.554000	5.48	.970200	.80	.583800	6.28	.416200	1
60'	9.554329	5.48	9.970152	.80	9.584177	6.28	10.415823	0'
110°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	69°

21°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	158°
0'	9.554329	5.48	9.970152	.82	9.584177	6.30	10.415823	60'
1	.554658	5.46	.970103	.80	.584555	6.28	.415445	59
2	.554987	5.47	.970055	.82	.584932	6.28	.415068	58
3	.555315	5.47	.970006	.82	.585309	6.28	.414691	57
4	.555643	5.47	.969957	.82	.585686	6.28	.414314	56
5	.555971	5.47	.969909	.80	.586062	6.27	.413938	55
6	.556299	5.45	.969860	.82	.586439	6.28	.413561	54
7	.556626	5.45	.969811	.82	.586815	6.27	.413185	53
8	.556953	5.45	.969762	.82	.587190	6.25	.412810	52
9	.557280	5.43	.969714	.80	.587566	6.27	.412434	51
10	.557606	5.43	.969665	.82	.587941	6.25	.412059	50
11	9.557932	5.43	9.969616	.82	9.588316	6.25	10.411684	49
12	.558258	5.42	.969567	.82	.588691	6.25	.411309	48
13	.558583	5.43	.969518	.82	.589066	6.23	.410934	47
14	.558909	5.42	.969469	.82	.589440	6.23	.410560	46
15	.559234	5.40	.969420	.82	.589814	6.23	.410186	45
16	.559558	5.42	.969370	.83	.590188	6.23	.409812	44
17	.559883	5.40	.969321	.82	.590562	6.23	.409438	43
18	.560207	5.40	.969272	.82	.590935	6.22	.409065	42
19	.560531	5.40	.969223	.83	.591308	6.22	.408692	41
20	.560855	5.38	.969173	.82	.591681	6.22	.408319	40
21	9.561178	5.38	9.969124	.82	9.592054	6.20	10.407946	39
22	.561501	5.38	.969075	.83	.592426	6.22	.407574	38
23	.561824	5.37	.969025	.82	.592799	6.20	.407201	37
24	.562146	5.37	.968976	.83	.593171	6.18	.406829	36
25	.562468	5.37	.968926	.82	.593542	6.20	.406458	35
26	.562790	5.37	.968877	.83	.593914	6.18	.406086	34
27	.563112	5.35	.968827	.83	.594285	6.18	.405715	33
28	.563433	5.37	.968777	.82	.594656	6.18	.405344	32
29	.563755	5.33	.968728	.83	.595027	6.18	.404973	31
30	.564075	5.35	.968678	.83	.595398	6.17	.404602	30
31	9.564396	5.33	9.968628	.83	9.595768	6.17	10.404232	29
32	.564716	5.33	.968578	.83	.596138	6.17	.403862	28
33	.565036	5.33	.968528	.82	.596508	6.17	.403492	27
34	.565356	5.33	.968479	.82	.596878	6.15	.403122	26
35	.565676	5.32	.968429	.83	.597247	6.15	.402753	25
36	.565995	5.32	.968379	.83	.597616	6.15	.402384	24
37	.566314	5.30	.968329	.85	.597985	6.15	.402015	23
38	.566632	5.32	.968278	.83	.598354	6.13	.401646	22
39	.566951	5.30	.968228	.83	.598722	6.15	.401278	21
40	.567269	5.30	.968178	.83	.599091	6.13	.400909	20
41	9.567587	5.28	9.968128	.83	9.599459	6.13	10.400541	19
42	.567904	5.30	.968078	.85	.599827	6.12	.400173	18
43	.568222	5.28	.968027	.83	.600194	6.13	.399806	17
44	.568539	5.28	.967977	.83	.600562	6.12	.399438	16
45	.568856	5.27	.967927	.85	.600929	6.12	.399071	15
46	.569172	5.27	.967876	.83	.601296	6.12	.398704	14
47	.569488	5.27	.967826	.85	.601663	6.12	.398337	13
48	.569804	5.27	.967775	.83	.602029	6.10	.397971	12
49	.570120	5.25	.967725	.85	.602395	6.10	.397605	11
50	.570435	5.27	.967674	.83	.602761	6.10	.397239	10
51	9.570751	5.25	9.967624	.85	9.603127	6.10	10.396873	9
52	.571066	5.23	.967573	.85	.603493	6.08	.396507	8
53	.571380	5.25	.967522	.85	.603858	6.08	.396142	7
54	.571695	5.23	.967471	.83	.604223	6.08	.395777	6
55	.572009	5.23	.967421	.85	.604588	6.08	.395412	5
56	.572323	5.22	.967370	.85	.604953	6.07	.395047	4
57	.572636	5.23	.967319	.85	.605317	6.08	.394683	3
58	.572950	5.22	.967268	.85	.605682	6.07	.394318	2
59	.573263	5.20	.967217	.85	.606046	6.07	.393954	1
60'	9.573575		9.967166		9.606410		10.393590	0'
111°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	68°

22°	Sine.	D. 1'.	Cbsine.	D. 1'.	Tang.	D. 1'.	Cotang.	157°
0'	9.573575		9.967166		9.606410		10.393590	60'
1	.573888	5.22	.967115	.85	.606773	6.05	.393227	59
2	.574200	5.20	.967064	.85	.607137	6.07	.392863	58
3	.574512	5.20	.967013	.85	.607500	6.05	.392500	57
4	.574824	5.20	.966961	.87	.607863	6.05	.392137	56
5	.575136	5.18	.966910	.85	.608225	6.03	.391775	55
6	.575447	5.18	.966859	.85	.608588	6.05	.391412	54
7	.575758	5.18	.966808	.85	.608950	6.03	.391050	53
8	.576069	5.17	.966756	.87	.609312	6.03	.390688	52
9	.576379	5.17	.966705	.85	.609674	6.03	.390326	51
10	.576689	5.17	.966653	.87	.610036	6.03	.389964	50
11	9.576999		9.966602		9.610397		10.389603	49
12	.577309	5.17	.966550	.87	.610759	6.03	.389241	48
13	.577618	5.15	.966499	.85	.611120	6.02	.388880	47
14	.577927	5.15	.966447	.87	.611480	6.00	.388520	46
15	.578236	5.15	.966395	.87	.611841	6.02	.388159	45
16	.578545	5.13	.966344	.85	.612201	6.00	.387799	44
17	.578853	5.13	.966292	.87	.612561	6.00	.387439	43
18	.579162	5.13	.966240	.87	.612921	6.00	.387079	42
19	.579470	5.12	.966188	.87	.613281	6.00	.386719	41
20	.579777	5.13	.966136	.85	.613641	5.98	.386359	40
21	9.580085		9.966085		9.614000		10.386000	39
22	.580392	5.12	.966033	.87	.614359	5.98	.385641	38
23	.580699	5.12	.965981	.87	.614718	5.98	.385282	37
24	.581005	5.10	.965929	.87	.615077	5.97	.384923	36
25	.581312	5.12	.965876	.88	.615435	5.97	.384565	35
26	.581618	5.10	.965824	.87	.615793	5.97	.384207	34
27	.581924	5.10	.965772	.87	.616151	5.97	.383849	33
28	.582229	5.08	.965720	.87	.616509	5.97	.383491	32
29	.582535	5.10	.965668	.87	.616867	5.97	.383133	31
30	.582840	5.08	.965615	.88	.617224	5.95	.382776	30
31	9.583145		9.965563		9.617582		10.382418	29
32	.583449	5.07	.965511	.87	.617939	5.95	.382061	28
33	.583754	5.08	.965458	.88	.618295	5.93	.381705	27
34	.584058	5.07	.965406	.87	.618652	5.95	.381348	26
35	.584361	5.05	.965353	.88	.619008	5.93	.380992	25
36	.584665	5.07	.965301	.87	.619364	5.93	.380636	24
37	.584968	5.05	.965248	.88	.619720	5.93	.380280	23
38	.585272	5.07	.965195	.88	.620076	5.93	.379924	22
39	.585574	5.03	.965143	.87	.620432	5.93	.379568	21
40	.585877	5.05	.965090	.88	.620787	5.92	.379213	20
41	9.586179		9.965037		9.621142		10.378858	19
42	.586482	5.05	.964984	.88	.621497	5.92	.378503	18
43	.586783	5.02	.964931	.88	.621852	5.92	.378148	17
44	.587085	5.03	.964879	.87	.622207	5.92	.377793	16
45	.587386	5.02	.964826	.88	.622561	5.90	.377439	15
46	.587688	5.03	.964773	.88	.622915	5.90	.377085	14
47	.587989	5.02	.964720	.88	.623269	5.90	.376731	13
48	.588289	5.00	.964666	.90	.623623	5.90	.376377	12
49	.588590	5.02	.964613	.88	.623976	5.88	.376024	11
50	.588890	5.00	.964560	.88	.624330	5.90	.375670	10
51	9.589190		9.964507		9.624683		10.375317	9
52	.589489	4.98	.964454	.88	.625036	5.88	.374964	8
53	.589789	5.00	.964400	.90	.625388	5.87	.374612	7
54	.590088	4.95	.964347	.88	.625741	5.88	.374259	6
55	.590387	4.98	.964294	.88	.626093	5.87	.373907	5
56	.590686	4.97	.964240	.90	.626445	5.87	.373555	4
57	.590984	4.97	.964187	.88	.626797	5.87	.373203	3
58	.591282	4.97	.964133	.90	.627149	5.87	.372851	2
59	.591580	4.97	.964080	.88	.627501	5.87	.372499	1
60'	9.591878		9.964026		9.627852		10.372148	0'
112°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	57°

23°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 156°	
0'	9.591878		9.964026		9.627852		10.372148	60'
1	.592176	4.97	.963972	.90	.628203	5.85	.371797	59
2	.592473	4.95	.963919	.88	.628554	5.85	.371446	58
3	.592770	4.95	.963865	.90	.628905	5.85	.371095	57
4	.593067	4.95	.963811	.90	.629255	5.83	.370745	56
5	.593362	4.93	.963757	.90	.629606	5.85	.370394	55
6	.593659	4.93	.963704	.88	.629956	5.83	.370044	54
7	.593955	4.93	.963650	.90	.630306	5.83	.369694	53
8	.594251	4.93	.963596	.90	.630656	5.83	.369344	52
9	.594547	4.93	.963542	.90	.631005	5.82	.368995	51
10	.594842	4.92	.963488	.90	.631355	5.83	.368645	50
		4.92		.90		5.82		
11	9.595137	4.92	9.963434	.92	9.631704	5.82	10.368296	49
12	.595432	4.92	.963379	.90	.632053	5.82	.367947	48
13	.595727	4.92	.963325	.90	.632402	5.82	.367598	47
14	.596021	4.90	.963271	.90	.632750	5.80	.367250	46
15	.596315	4.90	.963217	.90	.633099	5.82	.366901	45
16	.596609	4.90	.963163	.90	.633447	5.80	.366553	44
17	.596903	4.90	.963108	.92	.633795	5.80	.366205	43
18	.597196	4.88	.963054	.90	.634143	5.80	.365857	42
19	.597490	4.90	.962999	.92	.634490	5.78	.365510	41
20	.597783	4.88	.962945	.90	.634838	5.80	.365162	40
		4.87		.92		5.78		
21	9.598075	4.88	9.962890	.90	9.635185	5.78	10.364815	39
22	.598368	4.87	.962836	.90	.635532	5.78	.364468	38
23	.598660	4.87	.962781	.92	.635879	5.78	.364121	37
24	.598952	4.87	.962727	.90	.636226	5.78	.363774	36
25	.599244	4.87	.962672	.92	.636572	5.77	.363428	35
26	.599536	4.87	.962617	.92	.636919	5.78	.363081	34
27	.599827	4.85	.962562	.92	.637265	5.77	.362735	33
28	.600118	4.85	.962508	.90	.637611	5.77	.362389	32
29	.600409	4.85	.962453	.92	.637956	5.75	.362044	31
30	.600700	4.85	.962398	.92	.638302	5.77	.361698	30
		4.83		.92		5.75		
31	9.600990	4.83	9.962343	.92	9.638647	5.75	10.361353	29
32	.601280	4.83	.962288	.92	.638992	5.75	.361008	28
33	.601570	4.83	.962233	.92	.639337	5.75	.360663	27
34	.601860	4.83	.962178	.92	.639682	5.75	.360318	26
35	.602150	4.83	.962123	.92	.640027	5.75	.359973	25
36	.602439	4.82	.962067	.93	.640371	5.73	.359629	24
37	.602728	4.82	.962012	.92	.640716	5.75	.359284	23
38	.603017	4.82	.961957	.92	.641060	5.73	.358940	22
39	.603305	4.80	.961902	.92	.641404	5.73	.358596	21
40	.603594	4.82	.961846	.93	.641747	5.72	.358253	20
		4.80		.92		5.73		
41	9.603882	4.80	9.961791	.93	9.642091	5.72	10.357909	19
42	.604170	4.78	.961735	.92	.642434	5.72	.357566	18
43	.604457	4.80	.961680	.93	.642777	5.72	.357223	17
44	.604745	4.80	.961624	.92	.643120	5.72	.356880	16
45	.605032	4.78	.961569	.93	.643463	5.72	.356537	15
46	.605319	4.78	.961513	.93	.643806	5.72	.356194	14
47	.605606	4.78	.961458	.92	.644148	5.70	.355852	13
48	.605892	4.77	.961402	.93	.644490	5.70	.355510	12
49	.606179	4.78	.961346	.93	.644832	5.70	.355168	11
50	.606465	4.77	.961290	.93	.645174	5.70	.354826	10
		4.77		.92				
51	9.606751	4.75	9.961235	.93	9.645516	5.68	10.354484	9
52	.607036	4.77	.961179	.93	.645857	5.70	.354143	8
53	.607322	4.75	.961123	.93	.646199	5.68	.353801	7
54	.607607	4.75	.961067	.93	.646540	5.68	.353460	6
55	.607892	4.75	.961011	.93	.646881	5.68	.353119	5
56	.608177	4.75	.960955	.93	.647222	5.68	.352778	4
57	.608461	4.73	.960899	.93	.647562	5.67	.352438	3
58	.608745	4.73	.960843	.93	.647903	5.68	.352097	2
59	.609029	4.73	.960786	.95	.648243	5.67	.351757	1
60'	9.609313	4.73	9.960730	.93	9.648583	5.67	10.351417	0'

113°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	66°
------	---------	--------	-------	--------	---------	--------	-------	-----

24°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 155°	
0'	9.609313	4.73	9.960730	.93	9.648583	5.67	10.351417	60'
1	.609597	4.72	.960674	.93	.648923	5.67	.351077	59
2	.609880	4.73	.960618	.95	.649263	5.65	.350737	58
3	.610164	4.72	.960561	.93	.649602	5.67	.350398	57
4	.610447	4.70	.960505	.95	.649942	5.65	.350058	56
5	.610729	4.72	.960448	.93	.650281	5.65	.349719	55
6	.611012	4.70	.960392	.95	.650620	5.65	.349380	54
7	.611294	4.70	.960335	.93	.650959	5.63	.349041	53
8	.611576	4.70	.960279	.95	.651297	5.65	.348703	52
9	.611858	4.70	.960222	.95	.651636	5.63	.348364	51
10	.612140	4.68	.960165	.93	.651974	5.63	.348026	50
11	9.612421	4.68	9.960109	.95	9.652312	5.63	10.347688	49
12	.612702	4.68	.960052	.95	.652650	5.63	.347350	48
13	.612983	4.68	.959995	.95	.652988	5.63	.347012	47
14	.613264	4.68	.959938	.93	.653326	5.62	.346674	46
15	.613545	4.67	.959882	.95	.653663	5.62	.346337	45
16	.613825	4.67	.959825	.95	.654000	5.62	.346000	44
17	.614105	4.67	.959768	.95	.654337	5.62	.345663	43
18	.614385	4.67	.959711	.95	.654674	5.62	.345326	42
19	.614665	4.65	.959654	.97	.655011	5.62	.344989	41
20	.614944	4.65	.959596	.95	.655348	5.60	.344652	40
21	9.615223	4.65	9.959539	.95	9.655684	5.60	10.344316	39
22	.615502	4.65	.959482	.95	.656020	5.60	.343980	38
23	.615781	4.65	.959425	.95	.656356	5.60	.343644	37
24	.616060	4.63	.959368	.97	.656692	5.60	.343308	36
25	.616338	4.63	.959310	.95	.657028	5.60	.342972	35
26	.616616	4.63	.959253	.97	.657364	5.58	.342636	34
27	.616894	4.63	.959195	.95	.657699	5.58	.342301	33
28	.617172	4.63	.959138	.97	.658034	5.58	.341966	32
29	.617450	4.62	.959080	.95	.658369	5.58	.341631	31
30	.617727	4.62	.959023	.97	.658704	5.58	.341296	30
31	9.618004	4.62	9.958965	.95	9.659039	5.57	10.340961	29
32	.618281	4.62	.958908	.97	.659373	5.58	.340627	28
33	.618558	4.60	.958850	.97	.659708	5.57	.340292	27
34	.618834	4.60	.958792	.97	.660042	5.57	.339958	26
35	.619110	4.60	.958734	.95	.660376	5.57	.339624	25
36	.619386	4.60	.958677	.97	.660710	5.55	.339290	24
37	.619662	4.60	.958619	.97	.661043	5.57	.338957	23
38	.619933	4.58	.958561	.97	.661377	5.55	.338623	22
39	.620213	4.58	.958503	.97	.661710	5.55	.338290	21
40	.620488	4.58	.958445	.97	.662043	5.55	.337957	20
41	9.620763	4.58	9.958387	.97	9.662376	5.55	10.337624	19
42	.621038	4.58	.958329	.97	.662709	5.55	.337291	18
43	.621313	4.57	.958271	.97	.663042	5.55	.336958	17
44	.621587	4.57	.958213	.98	.663375	5.53	.336625	16
45	.621861	4.57	.958154	.97	.663707	5.53	.336293	15
46	.622135	4.57	.958096	.97	.664039	5.53	.335961	14
47	.622409	4.55	.958038	.98	.664371	5.53	.335629	13
48	.622682	4.57	.957979	.97	.664703	5.53	.335297	12
49	.622956	4.55	.957921	.97	.665035	5.52	.334965	11
50	.623229	4.55	.957863	.98	.665366	5.53	.334634	10
51	9.623502	4.53	9.957804	.97	9.665698	5.52	10.334302	9
52	.623774	4.55	.957746	.98	.666029	5.52	.333971	8
53	.624047	4.53	.957687	.98	.666360	5.52	.333640	7
54	.624319	4.53	.957628	.97	.666691	5.50	.333309	6
55	.624591	4.53	.957570	.98	.667021	5.52	.332979	5
56	.624863	4.53	.957511	.98	.667352	5.50	.332648	4
57	.625135	4.52	.957452	.98	.667682	5.50	.332318	3
58	.625406	4.52	.957393	.98	.668013	5.50	.331987	2
59	.625677	4.52	.957335	.97	.668343	5.50	.331657	1
60'	9.625948		9.957276	.98	9.668673		10.331327	0'
114° Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	65°	

25°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	154°
0'	9.625948		9.957276		9.668673		10.331327	60'
1	.626219	4.52	.957217	.98	.669002	5.48	.330998	59
2	.626490	4.52	.957158	.98	.669332	5.50	.330668	58
3	.626760	4.50	.957099	.98	.669661	5.48	.330339	57
4	.627030	4.50	.957040	.98	.669991	5.50	.330009	56
5	.627300	4.50	.956981	.98	.670320	5.48	.329680	55
6	.627570	4.50	.956921	1.00	.670649	5.48	.329351	54
7	.627840	4.50	.956862	.98	.670977	5.47	.329023	53
8	.628109	4.48	.956803	.98	.671306	5.48	.328694	52
9	.628378	4.48	.956744	.98	.671635	5.48	.328365	51
10	.628647	4.48	.956684	1.00	.671963	5.47	.328037	50
11	9.628916		9.956625		9.672291		10.327709	49
12	.629185	4.48	.956566	.98	.672619	5.47	.327381	48
13	.629453	4.47	.956506	1.00	.672947	5.47	.327053	47
14	.629721	4.47	.956447	.98	.673274	5.45	.326726	46
15	.629989	4.47	.956387	1.00	.673602	5.47	.326398	45
16	.630257	4.47	.956327	1.00	.673929	5.45	.326071	44
17	.630524	4.45	.956268	.98	.674257	5.47	.325743	43
18	.630792	4.47	.956208	1.00	.674584	5.45	.325416	42
19	.631059	4.45	.956148	1.00	.674911	5.45	.325089	41
20	.631326	4.45	.956089	.98	.675237	5.43	.324763	40
21	9.631593		9.956029		9.675564		10.324436	39
22	.631859	4.43	.955969	1.00	.675890	5.43	.324110	38
23	.632125	4.43	.955909	1.00	.676217	5.45	.323783	37
24	.632392	4.45	.955849	1.00	.676543	5.43	.323457	36
25	.632658	4.43	.955789	1.00	.676869	5.43	.323131	35
26	.632923	4.42	.955729	1.00	.677194	5.42	.322806	34
27	.633189	4.43	.955669	1.00	.677520	5.43	.322480	33
28	.633454	4.42	.955609	1.00	.677846	5.43	.322154	32
29	.633719	4.42	.955548	.98	.678171	5.42	.321829	31
30	.633984	4.42	.955488	1.00	.678496	5.42	.321504	30
31	9.634249		9.955428		9.678821		10.321179	29
32	.634514	4.42	.955368	1.00	.679146	5.42	.320854	28
33	.634778	4.40	.955307	1.02	.679471	5.42	.320529	27
34	.635042	4.40	.955247	1.00	.679795	5.40	.320205	26
35	.635306	4.40	.955186	1.02	.680120	5.42	.319880	25
36	.635570	4.40	.955126	1.00	.680444	5.40	.319556	24
37	.635834	4.40	.955065	1.02	.680768	5.40	.319232	23
38	.636097	4.38	.955005	1.00	.681092	5.40	.318908	22
39	.636360	4.38	.954944	1.02	.681416	5.40	.318584	21
40	.636623	4.38	.954883	1.00	.681740	5.40	.318260	20
41	9.636886		9.954823		9.682063		10.317937	19
42	.637148	4.37	.954762	1.02	.682387	5.40	.317613	18
43	.637411	4.38	.954701	1.00	.682710	5.38	.317290	17
44	.637673	4.37	.954640	1.02	.683033	5.38	.316967	16
45	.637935	4.37	.954579	1.00	.683356	5.38	.316644	15
46	.638197	4.37	.954518	1.02	.683679	5.38	.316321	14
47	.638458	4.35	.954457	1.00	.684001	5.37	.315999	13
48	.638720	4.37	.954396	1.02	.684324	5.38	.315676	12
49	.638981	4.35	.954335	1.00	.684646	5.37	.315354	11
50	.639242	4.35	.954274	1.02	.684968	5.37	.315032	10
51	9.639503		9.954213		9.685290		10.314710	9
52	.639764	4.35	.954152	1.02	.685612	5.37	.314388	8
53	.640024	4.33	.954090	1.00	.685934	5.37	.314066	7
54	.640284	4.33	.954029	1.02	.686255	5.35	.313745	6
55	.640544	4.33	.953968	1.00	.686577	5.37	.313423	5
56	.640804	4.33	.953906	1.03	.686898	5.35	.313102	4
57	.641064	4.33	.953845	1.00	.687219	5.35	.312781	3
58	.641324	4.32	.953783	1.03	.687540	5.35	.312460	2
59	.641583	4.32	.953722	1.00	.687861	5.35	.312139	1
60'	9.641842		9.953660		9.688182		10.311818	0'
115°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	64°

26°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	153°
0'	9.641842	4.32	9.953660	1.02	9.688182	5.33	10.311818	60'
1	.642101	4.32	.953599	1.03	.688502	5.35	.311498	59
2	.642360	4.30	.953537	1.03	.688823	5.33	.311177	58
3	.642618	4.32	.953475	1.03	.689143	5.33	.310857	57
4	.642877	4.30	.953413	1.02	.689463	5.33	.310537	56
5	.643135	4.30	.953352	1.03	.689783	5.33	.310217	55
6	.643393	4.28	.953290	1.03	.690103	5.33	.309897	54
7	.643650	4.30	.953228	1.03	.690423	5.32	.309577	53
8	.643908	4.28	.953166	1.03	.690742	5.33	.309258	52
9	.644165	4.30	.953104	1.03	.691062	5.32	.308938	51
10	.644423	4.28	.953042	1.03	.691381	5.32	.308619	50
11	9.644680	4.27	9.952980	1.03	9.691700	5.32	10.308300	49
12	.644936	4.28	.952918	1.05	.692019	5.32	.307981	48
13	.645193	4.28	.952855	1.03	.692338	5.30	.307662	47
14	.645450	4.27	.952793	1.03	.692656	5.32	.307344	46
15	.645706	4.27	.952731	1.03	.692975	5.30	.307025	45
16	.645962	4.27	.952669	1.05	.693293	5.32	.306707	44
17	.646218	4.27	.952606	1.03	.693612	5.30	.306388	43
18	.646474	4.25	.952544	1.05	.693930	5.30	.306070	42
19	.646729	4.25	.952481	1.03	.694248	5.30	.305752	41
20	.646984	4.27	.952419	1.05	.694566	5.28	.305434	40
21	9.647240	4.23	9.952356	1.03	9.694883	5.30	10.305117	39
22	.647494	4.25	.952294	1.05	.695201	5.28	.304799	38
23	.647749	4.25	.952231	1.05	.695518	5.30	.304482	37
24	.648004	4.23	.952168	1.03	.695836	5.28	.304164	36
25	.648258	4.23	.952106	1.05	.696153	5.28	.303847	35
26	.648512	4.23	.952043	1.05	.696470	5.28	.303530	34
27	.648766	4.23	.951980	1.05	.696787	5.27	.303213	33
28	.649020	4.23	.951917	1.05	.697103	5.28	.302897	32
29	.649274	4.22	.951854	1.05	.697420	5.27	.302580	31
30	.649527	4.23	.951791	1.05	.697736	5.28	.302264	30
31	9.649781	4.22	9.951728	1.05	9.698053	5.27	10.301947	29
32	.650034	4.22	.951665	1.05	.698369	5.27	.301631	28
33	.650287	4.20	.951602	1.05	.698685	5.27	.301315	27
34	.650539	4.22	.951539	1.05	.699001	5.25	.300999	26
35	.650792	4.22	.951476	1.07	.699316	5.27	.300684	25
36	.651044	4.22	.951412	1.05	.699632	5.25	.300368	24
37	.651297	4.20	.951349	1.05	.699947	5.27	.300053	23
38	.651549	4.18	.951286	1.07	.700263	5.25	.299737	22
39	.651800	4.20	.951222	1.05	.700578	5.25	.299422	21
40	.652052	4.20	.951159	1.05	.700893	5.25	.299107	20
41	9.652304	4.18	9.951096	1.07	9.701208	5.25	10.298792	19
42	.652555	4.18	.951032	1.07	.701523	5.23	.298477	18
43	.652806	4.18	.950968	1.05	.701837	5.25	.298163	17
44	.653057	4.18	.950905	1.07	.702152	5.23	.297848	16
45	.653308	4.17	.950841	1.05	.702466	5.25	.297534	15
46	.653558	4.17	.950778	1.07	.702781	5.23	.297219	14
47	.653808	4.18	.950714	1.07	.703095	5.23	.296905	13
48	.654059	4.17	.950650	1.07	.703409	5.22	.296591	12
49	.654309	4.15	.950586	1.07	.703722	5.23	.296278	11
50	.654558	4.17	.950522	1.07	.704036	5.23	.295964	10
51	9.654808	4.17	9.950458	1.07	9.704350	5.22	10.295650	9
52	.655058	4.15	.950394	1.07	.704663	5.22	.295337	8
53	.655307	4.15	.950330	1.07	.704976	5.23	.295024	7
54	.655556	4.15	.950266	1.07	.705290	5.22	.294710	6
55	.655805	4.15	.950202	1.07	.705603	5.22	.294397	5
56	.656054	4.13	.950138	1.07	.705916	5.20	.294084	4
57	.656302	4.15	.950074	1.07	.706228	5.22	.293772	3
58	.656551	4.13	.950010	1.08	.706541	5.22	.293459	2
59	.656799	4.13	.949945	1.07	.706854	5.20	.293146	1
60'	9.657047		9.949881		9.707166		10.292834	0'
116°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	63°

116°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	63°
------	---------	--------	-------	--------	---------	--------	-------	-----

27°	Sine.	D. 1°.	Cosine.	D. 1°.	Tang.	D. 1°.	Cotang.	152°
0'	9.657047		9.949881		9.707166		10.292834	60'
1	.657295	4.13	.949816	1.08	.707478	5.20	.292522	59
2	.657542	4.12	.949752	1.07	.707790	5.20	.292210	58
3	.657790	4.13	.949688	1.07	.708102	5.20	.291898	57
4	.658037	4.12	.949623	1.08	.708414	5.20	.291586	56
5	.658284	4.12	.949558	1.08	.708726	5.20	.291274	55
6	.658531	4.12	.949494	1.07	.709037	5.18	.290963	54
7	.658778	4.12	.949429	1.08	.709349	5.20	.290651	53
8	.659025	4.12	.949364	1.08	.709660	5.18	.290340	52
9	.659271	4.10	.949300	1.07	.709971	5.18	.290029	51
10	.659517	4.10	.949235	1.08	.710282	5.18	.289718	50
11	9.659763	4.10	9.949170	1.08	9.710593	5.18	10.289407	49
12	.660009	4.10	.949105	1.08	.710904	5.18	.289096	48
13	.660255	4.10	.949040	1.08	.711215	5.17	.288785	47
14	.660501	4.08	.948975	1.08	.711525	5.17	.288475	46
15	.660746	4.08	.948910	1.08	.711836	5.17	.288164	45
16	.660991	4.08	.948845	1.08	.712146	5.17	.287854	44
17	.661236	4.08	.948780	1.08	.712456	5.17	.287544	43
18	.661481	4.08	.948715	1.08	.712766	5.17	.287234	42
19	.661726	4.07	.948650	1.10	.713076	5.17	.286924	41
20	.661970	4.07	.948584	1.08	.713386	5.17	.286614	40
21	9.662214	4.08	9.948519	1.08	9.713696	5.15	10.286304	39
22	.662459	4.07	.948454	1.10	.714005	5.15	.285995	38
23	.662703	4.05	.948388	1.08	.714314	5.17	.285686	37
24	.662946	4.07	.948323	1.10	.714624	5.15	.285376	36
25	.663190	4.05	.948257	1.08	.714933	5.15	.285067	35
26	.663433	4.07	.948192	1.10	.715242	5.15	.284758	34
27	.663677	4.05	.948126	1.10	.715551	5.15	.284449	33
28	.663920	4.05	.948060	1.08	.715860	5.13	.284140	32
29	.664163	4.05	.947995	1.10	.716168	5.15	.283832	31
30	.664406	4.03	.947929	1.10	.716477	5.13	.283523	30
31	9.664648	4.05	9.947863	1.10	9.716785	5.13	10.283215	29
32	.664891	4.03	.947797	1.10	.717093	5.13	.282907	28
33	.665133	4.03	.947731	1.10	.717401	5.13	.282599	27
34	.665375	4.03	.947665	1.08	.717709	5.13	.282291	26
35	.665617	4.03	.947600	1.12	.718017	5.13	.281983	25
36	.665859	4.02	.947533	1.10	.718325	5.13	.281675	24
37	.666100	4.03	.947467	1.10	.718633	5.12	.281367	23
38	.666342	4.02	.947401	1.10	.718940	5.13	.281060	22
39	.666583	4.02	.947335	1.10	.719248	5.12	.280752	21
40	.666824	4.02	.947269	1.10	.719555	5.12	.280445	20
41	9.667065	4.00	9.947203	1.12	9.719862	5.12	10.280138	19
42	.667305	4.02	.947136	1.10	.720169	5.12	.279831	18
43	.667546	4.00	.947070	1.10	.720476	5.12	.279524	17
44	.667786	4.02	.947004	1.12	.720783	5.10	.279217	16
45	.668027	4.00	.946937	1.10	.721089	5.12	.278911	15
46	.668267	3.98	.946871	1.12	.721396	5.10	.278604	14
47	.668506	4.00	.946804	1.10	.721702	5.12	.278298	13
48	.668746	4.00	.946738	1.12	.722009	5.10	.277991	12
49	.668986	3.98	.946671	1.12	.722315	5.10	.277685	11
50	.669225	3.98	.946604	1.10	.722621	5.10	.277379	10
51	9.669464	3.98	9.946538	1.12	9.722927	5.08	10.277073	9
52	.669703	3.98	.946471	1.12	.723232	5.10	.276768	8
53	.669942	3.98	.946404	1.12	.723538	5.10	.276462	7
54	.670181	3.97	.946337	1.12	.723844	5.08	.276156	6
55	.670419	3.98	.946270	1.12	.724149	5.08	.275851	5
56	.670658	3.97	.946203	1.12	.724454	5.10	.275546	4
57	.670896	3.97	.946136	1.12	.724760	5.08	.275240	3
58	.671134	3.97	.946069	1.12	.725065	5.08	.274935	2
59	.671372	3.95	.946002	1.12	.725370	5.07	.274630	1
60'	9.671609		9.945935		9.725674		10.274326	0'

117°	Cosine.	D. 1°.	Sine.	D. 1°.	Cotang.	D. 1°.	Tang.	62°
------	---------	--------	-------	--------	---------	--------	-------	-----

28°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang. 151°	
0'	9.671609		9.945935		9.725674		10.274326	60'
1	.671847	3.97	.945868	1.12	.725979	5.08	.274021	59
2	.672084	3.95	.945800	1.13	.726284	5.08	.273716	58
3	.672321	3.95	.945733	1.12	.726588	5.07	.273412	57
4	.672558	3.95	.945666	1.12	.726892	5.07	.273108	56
5	.672795	3.95	.945598	1.13	.727197	5.08	.272803	55
6	.673032	3.95	.945531	1.12	.727501	5.07	.272499	54
7	.673268	3.93	.945464	1.12	.727805	5.07	.272195	53
8	.673505	3.95	.945396	1.13	.728109	5.07	.271891	52
9	.673741	3.93	.945328	1.13	.728412	5.05	.271588	51
10	.673977	3.93	.945261	1.12	.728716	5.07	.271284	50
11	9.674213		9.945193		9.729020		10.270980	49
12	.674448	3.92	.945125	1.13	.729323	5.05	.270677	48
13	.674684	3.93	.945058	1.12	.729626	5.05	.270374	47
14	.674919	3.92	.944990	1.13	.729929	5.05	.270071	46
15	.675155	3.93	.944922	1.13	.730233	5.07	.269767	45
16	.675390	3.92	.944854	1.13	.730535	5.03	.269465	44
17	.675624	3.90	.944786	1.13	.730838	5.05	.269162	43
18	.675859	3.92	.944718	1.13	.731141	5.05	.268859	42
19	.676094	3.92	.944650	1.13	.731444	5.05	.268556	41
20	.676328	3.90	.944582	1.13	.731746	5.03	.268254	40
21	9.676562		9.944514		9.732048		10.267952	39
22	.676796	3.90	.944446	1.13	.732351	5.05	.267649	38
23	.677030	3.90	.944377	1.15	.732653	5.03	.267347	37
24	.677264	3.90	.944309	1.13	.732955	5.03	.267045	36
25	.677498	3.90	.944241	1.13	.733257	5.03	.266743	35
26	.677731	3.88	.944172	1.15	.733558	5.02	.266442	34
27	.677964	3.88	.944104	1.13	.733860	5.03	.266140	33
28	.678197	3.88	.944036	1.13	.734162	5.03	.265838	32
29	.678430	3.88	.943967	1.15	.734463	5.02	.265537	31
30	.678663	3.88	.943899	1.13	.734764	5.02	.265236	30
31	9.678895		9.943830		9.735066		10.264934	29
32	.679128	3.88	.943761	1.15	.735367	5.02	.264633	28
33	.679360	3.87	.943693	1.13	.735668	5.02	.264332	27
34	.679592	3.87	.943624	1.15	.735969	5.02	.264031	26
35	.679824	3.87	.943555	1.15	.736269	5.00	.263731	25
36	.680056	3.87	.943486	1.15	.736570	5.02	.263430	24
37	.680288	3.87	.943417	1.15	.736870	5.00	.263130	23
38	.680519	3.85	.943348	1.15	.737171	5.02	.262829	22
39	.680750	3.85	.943279	1.15	.737471	5.00	.262529	21
40	.680982	3.87	.943210	1.15	.737771	5.00	.262229	20
41	9.681213		9.943141		9.738071		10.261929	19
42	.681443	3.83	.943072	1.15	.738371	5.00	.261629	18
43	.681674	3.85	.943003	1.15	.738671	5.00	.261329	17
44	.681905	3.85	.942934	1.15	.738971	5.00	.261029	16
45	.682135	3.83	.942864	1.17	.739271	5.00	.260729	15
46	.682365	3.83	.942795	1.15	.739570	4.98	.260430	14
47	.682595	3.83	.942726	1.15	.739870	5.00	.260130	13
48	.682825	3.83	.942656	1.17	.740169	4.98	.259831	12
49	.683055	3.83	.942587	1.15	.740468	4.98	.259532	11
50	.683284	3.82	.942517	1.17	.740767	4.98	.259233	10
51	9.683514		9.942448		9.741066		10.258934	9
52	.683743	3.82	.942378	1.17	.741365	4.98	.258635	8
53	.683972	3.82	.942308	1.17	.741664	4.98	.258336	7
54	.684201	3.82	.942239	1.15	.741962	4.97	.258038	6
55	.684430	3.82	.942169	1.17	.742261	4.98	.257739	5
56	.684658	3.80	.942099	1.17	.742559	4.97	.257441	4
57	.684887	3.82	.942029	1.17	.742858	4.98	.257142	3
58	.685115	3.80	.941959	1.17	.743156	4.97	.256844	2
59	.685343	3.80	.941889	1.17	.743454	4.97	.256546	1
60'	9.685571		9.941819		9.743752		10.256248	0'
118°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	61°

29°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 150°	
0'	9.685571	3.80	9.941819	1.17	9.743752	4.97	10.256248	60'
1	.685799	3.80	.941749	1.17	.744050	4.97	.255950	59
2	.686027	3.78	.941679	1.17	.744348	4.95	.255652	58
3	.686254	3.80	.941609	1.17	.744645	4.97	.255355	57
4	.686482	3.78	.941539	1.17	.744943	4.95	.255057	56
5	.686709	3.78	.941469	1.18	.745240	4.97	.254760	55
6	.686936	3.78	.941398	1.17	.745538	4.95	.254462	54
7	.687163	3.77	.941328	1.17	.745835	4.95	.254165	53
8	.687389	3.78	.941258	1.18	.746132	4.95	.253868	52
9	.687616	3.78	.941187	1.17	.746429	4.95	.253571	51
10	.687843	3.77	.941117	1.18	.746726	4.95	.253274	50
11	9.688069	3.77	9.941046	1.18	9.747023	4.93	10.252977	49
12	.688295	3.77	.940975	1.17	.747319	4.95	.252681	48
13	.688521	3.77	.940905	1.18	.747616	4.95	.252384	47
14	.688747	3.75	.940834	1.18	.747913	4.93	.252087	46
15	.688972	3.77	.940763	1.17	.748209	4.93	.251791	45
16	.689198	3.75	.940693	1.18	.748505	4.93	.251495	44
17	.689423	3.75	.940622	1.18	.748801	4.93	.251199	43
18	.689648	3.75	.940551	1.18	.749097	4.93	.250903	42
19	.689873	3.75	.940480	1.18	.749393	4.93	.250607	41
20	.690098	3.75	.940409	1.18	.749689	4.93	.250311	40
21	9.690323	3.75	9.940338	1.18	9.749985	4.93	10.250015	39
22	.690548	3.73	.940267	1.18	.750281	4.92	.249719	38
23	.690772	3.73	.940196	1.18	.750576	4.93	.249424	37
24	.690996	3.73	.940125	1.18	.750872	4.92	.249128	36
25	.691220	3.73	.940054	1.20	.751167	4.92	.248833	35
26	.691444	3.73	.939982	1.18	.751462	4.92	.248538	34
27	.691668	3.73	.939911	1.18	.751757	4.92	.248243	33
28	.691892	3.72	.939840	1.20	.752052	4.92	.247948	32
29	.692115	3.73	.939768	1.18	.752347	4.92	.247653	31
30	.692339	3.72	.939697	1.20	.752642	4.92	.247358	30
31	9.692562	3.72	9.939625	1.18	9.752937	4.90	10.247063	29
32	.692785	3.72	.939554	1.20	.753231	4.92	.246769	28
33	.693008	3.72	.939482	1.20	.753526	4.90	.246474	27
34	.693231	3.70	.939410	1.18	.753820	4.92	.246180	26
35	.693453	3.72	.939339	1.20	.754115	4.90	.245885	25
36	.693676	3.70	.939267	1.20	.754409	4.90	.245591	24
37	.693898	3.70	.939195	1.20	.754703	4.90	.245297	23
38	.694120	3.70	.939123	1.18	.754997	4.90	.245003	22
39	.694342	3.70	.939052	1.20	.755291	4.90	.244709	21
40	.694564	3.70	.938980	1.20	.755585	4.88	.244415	20
41	9.694786	3.68	9.938908	1.20	9.755878	4.90	10.244122	19
42	.695007	3.70	.938836	1.22	.756172	4.88	.243828	18
43	.695229	3.68	.938763	1.20	.756465	4.90	.243535	17
44	.695450	3.68	.938691	1.20	.756759	4.88	.243241	16
45	.695671	3.68	.938619	1.20	.757052	4.88	.242948	15
46	.695892	3.68	.938547	1.20	.757345	4.88	.242655	14
47	.696113	3.68	.938475	1.22	.757638	4.88	.242362	13
48	.696334	3.67	.938402	1.20	.757931	4.88	.242069	12
49	.696554	3.68	.938330	1.20	.758224	4.88	.241776	11
50	.696775	3.67	.938258	1.22	.758517	4.88	.241483	10
51	9.696995	3.67	9.938185	1.20	9.758810	4.87	10.241190	9
52	.697215	3.67	.938113	1.22	.759102	4.88	.240898	8
53	.697435	3.65	.938040	1.22	.759395	4.87	.240605	7
54	.697654	3.67	.937967	1.20	.759687	4.87	.240313	6
55	.697874	3.67	.937895	1.22	.759979	4.88	.240021	5
56	.698094	3.65	.937822	1.22	.760272	4.87	.239728	4
57	.698313	3.65	.937749	1.22	.760564	4.87	.239436	3
58	.698532	3.65	.937676	1.20	.760856	4.87	.239144	2
59	.698751	3.65	.937604	1.22	.761148	4.85	.238852	1
60'	9.698970	3.65	9.937531		9.761439		10.238561	0'
119° Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	60°	

30°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	149°
0'	9.688970	3.65	9.937531	1.22	9.761439	4.87	10.238561	60
1	.699189	3.63	.937458	1.22	.761731	4.87	.238269	59
2	.699407	3.65	.937385	1.22	.762023	4.87	.237977	58
3	.699626	3.63	.937312	1.23	.762314	4.85	.237686	57
4	.699844	3.63	.937238	1.22	.762605	4.87	.237394	56
5	.700062	3.63	.937165	1.22	.762897	4.85	.237103	55
6	.700280	3.63	.937092	1.22	.763188	4.85	.236812	54
7	.700498	3.63	.937019	1.22	.763479	4.85	.236521	53
8	.700716	3.62	.936946	1.23	.763770	4.85	.236230	52
9	.700933	3.63	.936872	1.22	.764061	4.85	.235939	51
10	.701151	3.62	.936799	1.23	.764352	4.85	.235648	50
11	9.701368	3.62	9.936725	1.22	9.764643	4.83	10.235357	49
12	.701585	3.62	.936652	1.23	.764933	4.85	.235067	48
13	.701802	3.62	.936578	1.22	.765224	4.83	.234776	47
14	.702019	3.62	.936505	1.23	.765514	4.85	.234486	46
15	.702236	3.60	.936431	1.23	.765805	4.83	.234195	45
16	.702452	3.62	.936357	1.22	.766095	4.83	.233905	44
17	.702669	3.60	.936284	1.23	.766385	4.83	.233615	43
18	.702885	3.60	.936210	1.23	.766675	4.83	.233325	42
19	.703101	3.60	.936136	1.23	.766965	4.83	.233035	41
20	.703317	3.60	.936062	1.23	.767255	4.83	.232745	40
21	9.703533	3.60	9.935988	1.23	9.767545	4.82	10.232455	39
22	.703749	3.58	.935914	1.23	.767834	4.83	.232166	38
23	.703964	3.58	.935840	1.23	.768124	4.83	.231876	37
24	.704179	3.60	.935766	1.23	.768414	4.82	.231586	36
25	.704395	3.58	.935692	1.23	.768703	4.82	.231297	35
26	.704610	3.58	.935618	1.23	.768992	4.82	.231008	34
27	.704825	3.58	.935543	1.25	.769281	4.82	.230719	33
28	.705040	3.57	.935469	1.23	.769571	4.82	.230429	32
29	.705254	3.58	.935395	1.25	.769860	4.82	.230140	31
30	.705469	3.57	.935320	1.23	.770148	4.82	.229852	30
31	9.705683	3.58	9.935246	1.25	9.770437	4.82	10.229563	29
32	.705898	3.57	.935171	1.23	.770726	4.82	.229274	28
33	.706112	3.57	.935097	1.25	.771015	4.80	.228985	27
34	.706326	3.55	.935022	1.23	.771303	4.82	.228697	26
35	.706539	3.57	.934948	1.25	.771592	4.82	.228408	25
36	.706753	3.57	.934873	1.25	.771880	4.80	.228120	24
37	.706967	3.55	.934798	1.25	.772168	4.82	.227832	23
38	.707180	3.55	.934723	1.23	.772457	4.80	.227543	22
39	.707393	3.55	.934649	1.25	.772745	4.80	.227255	21
40	.707606	3.55	.934574	1.25	.773033	4.80	.226967	20
41	9.707819	3.55	9.934499	1.25	9.773321	4.78	10.226679	19
42	.708032	3.55	.934424	1.25	.773608	4.80	.226392	18
43	.708245	3.55	.934349	1.25	.773896	4.80	.226104	17
44	.708458	3.53	.934274	1.25	.774184	4.80	.225816	16
45	.708670	3.53	.934199	1.27	.774471	4.78	.225529	15
46	.708882	3.53	.934123	1.25	.774759	4.78	.225241	14
47	.709094	3.53	.934048	1.25	.775046	4.78	.224954	13
48	.709306	3.53	.933973	1.25	.775333	4.78	.224667	12
49	.709518	3.53	.933898	1.27	.775621	4.80	.224379	11
50	.709730	3.52	.933822	1.25	.775908	4.78	.224092	10
51	9.709941	3.53	9.933747	1.27	9.776195	4.78	10.223805	9
52	.710153	3.52	.933671	1.25	.776482	4.77	.223518	8
53	.710364	3.52	.933596	1.27	.776768	4.78	.223232	7
54	.710575	3.52	.933520	1.25	.777055	4.78	.222945	6
55	.710786	3.52	.933445	1.27	.777342	4.77	.222658	5
56	.710997	3.52	.933369	1.27	.777628	4.78	.222372	4
57	.711208	3.52	.933293	1.27	.777915	4.77	.222085	3
58	.711419	3.50	.933217	1.27	.778201	4.78	.221799	2
59	.711629	3.50	.933141	1.25	.778488	4.77	.221512	1
60'	9.711839		9.933066		9.778774		10.221226	0'
120°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	69°

31°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	148°
0	9.711839	3.52	9.933066	1.27	9.778774	4.77	10.221226	60
1	.712050	3.50	.932990	1.27	.779060	4.77	.220940	59
2	.712260	3.48	.932914	1.27	.779346	4.77	.220654	58
3	.712469	3.50	.932838	1.27	.779632	4.77	.220368	57
4	.712679	3.50	.932762	1.27	.779918	4.77	.220082	56
5	.712889	3.48	.932685	1.28	.780203	4.75	.219797	55
6	.713098	3.50	.932609	1.27	.780489	4.77	.219511	54
7	.713308	3.48	.932533	1.27	.780775	4.77	.219225	53
8	.713517	3.48	.932457	1.27	.781060	4.75	.218940	52
9	.713726	3.48	.932380	1.28	.781346	4.77	.218654	51
10	.713935	3.48	.932304	1.27	.781631	4.75	.218369	50
11	9.714144	3.48	9.932228	1.27	9.781916	4.75	10.218084	49
12	.714352	3.47	.932151	1.28	.782201	4.75	.217799	48
13	.714561	3.48	.932075	1.27	.782486	4.75	.217514	47
14	.714769	3.47	.931998	1.28	.782771	4.75	.217229	46
15	.714978	3.48	.931921	1.28	.783056	4.75	.216944	45
16	.715186	3.47	.931845	1.27	.783341	4.75	.216659	44
17	.715394	3.47	.931768	1.28	.783626	4.75	.216374	43
18	.715602	3.47	.931691	1.28	.783910	4.73	.216090	42
19	.715809	3.45	.931614	1.28	.784195	4.75	.215805	41
20	.716017	3.47	.931537	1.28	.784479	4.73	.215521	40
21	9.716224	3.45	9.931460	1.28	9.784764	4.75	10.215236	39
22	.716432	3.47	.931383	1.28	.785048	4.73	.214952	38
23	.716639	3.45	.931306	1.28	.785332	4.73	.214668	37
24	.716846	3.45	.931229	1.28	.785616	4.73	.214384	36
25	.717053	3.43	.931152	1.28	.785900	4.73	.214100	35
26	.717259	3.43	.931075	1.28	.786184	4.73	.213816	34
27	.717466	3.45	.930998	1.28	.786468	4.73	.213532	33
28	.717673	3.45	.930921	1.28	.786752	4.73	.213248	32
29	.717879	3.43	.930843	1.30	.787036	4.73	.212964	31
30	.718085	3.43	.930766	1.28	.787319	4.72	.212681	30
31	9.718291	3.43	9.930688	1.30	9.787603	4.73	10.212397	29
32	.718497	3.43	.930611	1.30	.787886	4.73	.212114	28
33	.718703	3.43	.930533	1.30	.788170	4.73	.211830	27
34	.718909	3.42	.930456	1.28	.788453	4.72	.211547	26
35	.719114	3.42	.930378	1.30	.788736	4.72	.211264	25
36	.719320	3.43	.930300	1.30	.789019	4.72	.210981	24
37	.719525	3.42	.930223	1.28	.789302	4.72	.210698	23
38	.719730	3.42	.930145	1.30	.789585	4.72	.210415	22
39	.719935	3.42	.930067	1.30	.789868	4.72	.210132	21
40	.720140	3.42	.929989	1.30	.790151	4.72	.209849	20
41	9.720345	3.40	9.929911	1.30	9.790434	4.70	10.209566	19
42	.720549	3.42	.929833	1.30	.790716	4.72	.209284	18
43	.720754	3.40	.929755	1.30	.790999	4.70	.209001	17
44	.720958	3.40	.929677	1.30	.791281	4.70	.208719	16
45	.721162	3.40	.929599	1.30	.791563	4.70	.208437	15
46	.721366	3.40	.929521	1.30	.791846	4.72	.208154	14
47	.721570	3.40	.929442	1.32	.792128	4.70	.207872	13
48	.721774	3.40	.929364	1.30	.792410	4.70	.207590	12
49	.721978	3.40	.929286	1.30	.792692	4.70	.207308	11
50	.722181	3.38	.929207	1.32	.792974	4.70	.207026	10
51	9.722385	3.40	9.929129	1.30	9.793256	4.70	10.206744	9
52	.722588	3.38	.929050	1.32	.793538	4.68	.206462	8
53	.722791	3.38	.928972	1.30	.793819	4.70	.206181	7
54	.722994	3.38	.928893	1.32	.794101	4.70	.205899	6
55	.723197	3.38	.928815	1.30	.794383	4.70	.205617	5
56	.723400	3.38	.928736	1.32	.794664	4.68	.205336	4
57	.723603	3.38	.928657	1.32	.794946	4.70	.205054	3
58	.723805	3.37	.928578	1.32	.795227	4.68	.204773	2
59	.724007	3.37	.928499	1.32	.795508	4.68	.204492	1
60	9.724210	3.38	9.928420	1.32	9.795789	4.68	10.204211	0
121°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	58°

32°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	147°
0'	9.724210	3.37	9.928420	1.30	9.795789	4.68	10.204211	60'
1	.724412	3.37	.928342	1.32	.796070	4.68	.203930	59
2	.724614	3.37	.928263	1.33	.796351	4.68	.203649	58
3	.724816	3.37	.928183	1.33	.796632	4.68	.203368	57
4	.725017	3.35	.928104	1.32	.796913	4.68	.203087	56
5	.725219	3.37	.928025	1.32	.797194	4.68	.202806	55
6	.725420	3.35	.927946	1.32	.797474	4.67	.202526	54
7	.725622	3.37	.927867	1.32	.797755	4.68	.202245	53
8	.725823	3.35	.927787	1.33	.798036	4.68	.201964	52
9	.726024	3.35	.927708	1.32	.798316	4.67	.201684	51
10	.726225	3.35	.927629	1.33	.798596	4.68	.201404	50
11	9.726426	3.33	9.927549	1.32	9.798877	4.67	10.201123	49
12	.726626	3.35	.927470	1.33	.799157	4.67	.200843	48
13	.726827	3.33	.927390	1.33	.799437	4.67	.200563	47
14	.727027	3.33	.927310	1.33	.799717	4.67	.200283	46
15	.727228	3.35	.927231	1.32	.799997	4.67	.200003	45
16	.727428	3.33	.927151	1.33	.800277	4.67	.199723	44
17	.727628	3.33	.927071	1.33	.800557	4.67	.199443	43
18	.727828	3.33	.926991	1.33	.800836	4.65	.199164	42
19	.728027	3.32	.926911	1.33	.801116	4.67	.198884	41
20	.728227	3.33	.926831	1.33	.801396	4.67	.198604	40
21	9.728427	3.32	9.926751	1.33	9.801675	4.67	10.198325	39
22	.728626	3.32	.926671	1.33	.801955	4.65	.198045	38
23	.728825	3.32	.926591	1.33	.802234	4.65	.197766	37
24	.729024	3.32	.926511	1.33	.802513	4.65	.197487	36
25	.729223	3.32	.926431	1.33	.802792	4.65	.197208	35
26	.729422	3.32	.926351	1.33	.803072	4.67	.196928	34
27	.729621	3.32	.926270	1.35	.803351	4.65	.196649	33
28	.729820	3.32	.926190	1.33	.803630	4.65	.196370	32
29	.730018	3.30	.926110	1.33	.803909	4.65	.196091	31
30	.730217	3.32	.926029	1.35	.804187	4.63	.195813	30
31	9.730415	3.30	9.925949	1.33	9.804466	4.65	10.195534	29
32	.730613	3.30	.925868	1.35	.804745	4.65	.195255	28
33	.730811	3.30	.925788	1.33	.805023	4.63	.194977	27
34	.731009	3.28	.925707	1.35	.805302	4.65	.194698	26
35	.731206	3.30	.925626	1.35	.805580	4.63	.194420	25
36	.731404	3.30	.925545	1.35	.805859	4.65	.194141	24
37	.731602	3.30	.925465	1.33	.806137	4.63	.193863	23
38	.731799	3.28	.925384	1.35	.806415	4.63	.193585	22
39	.731996	3.28	.925303	1.35	.806693	4.63	.193307	21
40	.732193	3.28	.925222	1.35	.806971	4.63	.193029	20
41	9.732390	3.28	9.925141	1.35	9.807249	4.63	10.192751	19
42	.732587	3.28	.925060	1.35	.807527	4.63	.192473	18
43	.732784	3.27	.924979	1.37	.807805	4.63	.192195	17
44	.732980	3.28	.924897	1.35	.808083	4.63	.191917	16
45	.733177	3.27	.924816	1.35	.808361	4.62	.191639	15
46	.733373	3.27	.924735	1.35	.808638	4.62	.191362	14
47	.733569	3.27	.924654	1.37	.808916	4.63	.191084	13
48	.733765	3.27	.924572	1.37	.809193	4.62	.190807	12
49	.733961	3.27	.924491	1.35	.809471	4.63	.190529	11
50	.734157	3.27	.924409	1.37	.809748	4.62	.190252	10
51	9.734353	3.27	9.924328	1.35	9.810025	4.62	10.189975	9
52	.734549	3.25	.924246	1.37	.810302	4.62	.189698	8
53	.734744	3.25	.924164	1.37	.810580	4.63	.189420	7
54	.734939	3.25	.924083	1.35	.810857	4.62	.189143	6
55	.735135	3.27	.924001	1.37	.811134	4.62	.188866	5
56	.735330	3.25	.923919	1.37	.811410	4.60	.188590	4
57	.735525	3.25	.923837	1.37	.811687	4.62	.188313	3
58	.735719	3.23	.923755	1.37	.811964	4.62	.188036	2
59	.735914	3.25	.923673	1.37	.812241	4.62	.187759	1
60'	9.736109	3.25	9.923591	1.37	9.812517	4.60	10.187483	0'
122°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	57°

33°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 146°
0'	9.726109		9.923591		9.812517		10.187483
1	.736303	3.23	.923509	1.37	.812794	4.62	.187206
2	.736498	3.25	.923427	1.37	.813070	4.60	.186930
3	.736692	3.23	.923345	1.37	.813347	4.62	.186653
4	.736886	3.23	.923263	1.37	.813623	4.60	.186377
5	.737080	3.23	.923181	1.37	.813899	4.60	.186101
6	.737274	3.23	.923098	1.38	.814176	4.62	.185824
7	.737467	3.22	.923016	1.37	.814452	4.60	.185548
8	.737661	3.23	.922933	1.38	.814728	4.60	.185272
9	.737855	3.23	.922851	1.37	.815004	4.60	.184996
10	.738048	3.22	.922768	1.38	.815280	4.60	.184720
		3.22		1.37		4.58	
11	9.738241		9.922686		9.815555		10.184445
12	.738434	3.22	.922603	1.38	.815831	4.60	.184169
13	.738627	3.22	.922520	1.38	.816107	4.60	.183893
14	.738820	3.22	.922438	1.37	.816382	4.58	.183618
15	.739013	3.22	.922355	1.38	.816658	4.60	.183342
16	.739206	3.22	.922272	1.38	.816933	4.58	.183067
17	.739398	3.20	.922189	1.38	.817209	4.60	.182791
18	.739590	3.20	.922106	1.38	.817484	4.58	.182516
19	.739783	3.22	.922023	1.38	.817759	4.58	.182241
20	.739975	3.20	.921940	1.38	.818035	4.60	.181965
		3.20		1.38		4.58	
21	9.740167		9.921857		9.818310		10.181690
22	.740359	3.20	.921774	1.38	.818585	4.58	.181415
23	.740550	3.18	.921691	1.38	.818860	4.58	.181140
24	.740742	3.20	.921607	1.40	.819135	4.58	.180865
25	.740934	3.20	.921524	1.38	.819410	4.58	.180590
26	.741125	3.18	.921441	1.38	.819684	4.57	.180316
27	.741316	3.18	.921357	1.40	.819959	4.58	.180041
28	.741508	3.20	.921274	1.38	.820234	4.58	.179766
29	.741699	3.18	.921190	1.40	.820508	4.57	.179492
30	.741889	3.17	.921107	1.38	.820783	4.58	.179217
		3.18		1.40		4.57	
31	9.742080		9.921023		9.821057		10.178943
32	.742271	3.18	.920939	1.40	.821332	4.58	.178668
33	.742462	3.18	.920856	1.38	.821606	4.57	.178394
34	.742652	3.17	.920772	1.40	.821880	4.57	.178120
35	.742842	3.17	.920688	1.40	.822154	4.57	.177846
36	.743033	3.18	.920604	1.40	.822429	4.58	.177571
37	.743223	3.17	.920520	1.40	.822703	4.57	.177297
38	.743413	3.17	.920436	1.40	.822977	4.57	.177023
39	.743602	3.15	.920352	1.40	.823251	4.57	.176749
40	.743792	3.17	.920268	1.40	.823524	4.55	.176476
		3.17		1.40		4.57	
41	9.743982		9.920184		9.823798		10.176202
42	.744171	3.15	.920099	1.42	.824072	4.57	.175928
43	.744361	3.17	.920015	1.40	.824345	4.55	.175655
44	.744550	3.15	.919931	1.40	.824619	4.57	.175381
45	.744739	3.15	.919846	1.42	.824893	4.57	.175107
46	.744928	3.15	.919762	1.40	.825166	4.55	.174834
47	.745117	3.15	.919677	1.42	.825439	4.55	.174561
48	.745306	3.15	.919593	1.40	.825713	4.57	.174287
49	.745494	3.13	.919508	1.42	.825986	4.55	.174014
50	.745683	3.15	.919424	1.40	.826259	4.55	.173741
		3.13		1.42		4.55	
51	9.745871		9.919339		9.826532		10.173468
52	.746060	3.15	.919254	1.42	.826805	4.55	.173195
53	.746248	3.13	.919169	1.42	.827078	4.55	.172922
54	.746436	3.13	.919085	1.40	.827351	4.55	.172649
55	.746624	3.13	.919000	1.42	.827624	4.55	.172376
56	.746812	3.13	.918915	1.42	.827897	4.55	.172103
57	.746999	3.12	.918830	1.42	.828170	4.55	.171830
58	.747187	3.13	.918745	1.42	.828442	4.53	.171558
59	.747374	3.12	.918659	1.43	.828715	4.55	.171285
60'	9.747562		9.918574		9.828987		10.171013

123° Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	56°
--------------	--------	-------	--------	---------	--------	-------	-----

34°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	145°
0'	9.747562	3.12	9.918574	1.42	9.828987	4.55	10.171013	60
1	.747749	3.12	.918489	1.42	.829260	4.53	.170740	59
2	.747936	3.12	.918404	1.43	.829532	4.55	.170468	58
3	.748123	3.12	.918318	1.42	.829805	4.53	.170195	57
4	.748310	3.12	.918233	1.43	.830077	4.53	.169923	56
5	.748497	3.10	.918147	1.42	.830349	4.53	.169651	55
6	.748683	3.12	.918062	1.43	.830621	4.53	.169379	54
7	.748870	3.10	.917976	1.42	.830893	4.53	.169107	53
8	.749056	3.12	.917891	1.43	.831165	4.53	.168835	52
9	.749243	3.10	.917805	1.43	.831437	4.53	.168563	51
10	.749429	3.10	.917719	1.42	.831709	4.53	.168291	50
11	9.749615	3.10	9.917634	1.43	9.831981	4.53	10.168019	49
12	.749801	3.10	.917548	1.43	.832253	4.53	.167747	48
13	.749987	3.08	.917462	1.43	.832525	4.52	.167475	47
14	.750172	3.10	.917376	1.43	.832796	4.53	.167204	46
15	.750358	3.08	.917290	1.43	.833068	4.52	.166932	45
16	.750543	3.10	.917204	1.43	.833339	4.53	.166661	44
17	.750729	3.08	.917118	1.43	.833611	4.52	.166389	43
18	.750914	3.08	.917032	1.43	.833882	4.53	.166118	42
19	.751099	3.08	.916946	1.45	.834154	4.52	.165846	41
20	.751284	3.08	.916859	1.43	.834425	4.52	.165575	40
21	9.751469	3.08	9.916773	1.43	9.834696	4.52	10.165304	39
22	.751654	3.08	.916687	1.45	.834967	4.52	.165033	38
23	.751839	3.07	.916600	1.43	.835238	4.52	.164762	37
24	.752023	3.08	.916514	1.45	.835509	4.52	.164491	36
25	.752208	3.07	.916427	1.43	.835780	4.52	.164220	35
26	.752392	3.07	.916341	1.45	.836051	4.52	.163949	34
27	.752576	3.07	.916254	1.45	.836322	4.52	.163678	33
28	.752760	3.07	.916167	1.43	.836593	4.52	.163407	32
29	.752944	3.07	.916081	1.45	.836864	4.50	.163136	31
30	.753128	3.07	.915994	1.45	.837134	4.52	.162866	30
31	9.753312	3.05	9.915907	1.45	9.837405	4.50	10.162595	29
32	.753495	3.07	.915820	1.45	.837675	4.52	.162325	28
33	.753679	3.05	.915733	1.45	.837946	4.50	.162054	27
34	.753862	3.07	.915646	1.45	.838216	4.52	.161784	26
35	.754046	3.05	.915559	1.45	.838487	4.50	.161513	25
36	.754229	3.05	.915472	1.45	.838757	4.50	.161243	24
37	.754412	3.05	.915385	1.47	.839027	4.50	.160973	23
38	.754595	3.05	.915297	1.45	.839297	4.52	.160703	22
39	.754778	3.03	.915210	1.45	.839568	4.50	.160432	21
40	.754960	3.05	.915123	1.47	.839838	4.50	.160162	20
41	9.755143	3.05	9.915035	1.45	9.840108	4.50	10.159892	19
42	.755326	3.03	.914948	1.47	.840378	4.50	.159622	18
43	.755508	3.03	.914860	1.45	.840648	4.48	.159352	17
44	.755690	3.03	.914773	1.47	.840917	4.50	.159083	16
45	.755872	3.03	.914685	1.45	.841187	4.50	.158813	15
46	.756054	3.03	.914598	1.47	.841457	4.50	.158543	14
47	.756236	3.03	.914510	1.47	.841727	4.48	.158273	13
48	.756418	3.03	.914422	1.47	.841996	4.50	.158004	12
49	.756600	3.03	.914334	1.47	.842266	4.48	.157734	11
50	.756782	3.02	.914246	1.47	.842535	4.50	.157465	10
51	9.756963	3.02	9.914158	1.47	9.842805	4.48	10.157195	9
52	.757144	3.03	.914070	1.47	.843074	4.48	.156926	8
53	.757326	3.02	.913982	1.47	.843343	4.48	.156657	7
54	.757507	3.02	.913894	1.47	.843612	4.50	.156388	6
55	.757688	3.02	.913806	1.47	.843882	4.48	.156118	5
56	.757869	3.02	.913718	1.47	.844151	4.48	.155849	4
57	.758050	3.00	.913630	1.48	.844420	4.48	.155580	3
58	.758230	3.02	.913541	1.47	.844689	4.48	.155311	2
59	.758411	3.00	.913453	1.47	.844958	4.48	.155042	1
60'	9.758591	3.00	9.913365	1.47	9.845227	4.48	10.154773	0
124°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	55°

85°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	144°
0'	9.758591	3.02	9.913365	1.48	9.845227	4.48	10.154773	60'
1	.758772	3.00	.913276	1.48	.845496	4.47	.154504	59
2	.758952	3.00	.913187	1.47	.845764	4.48	.154236	58
3	.759132	3.00	.913099	1.48	.846033	4.48	.153967	57
4	.759312	3.00	.913010	1.47	.846302	4.47	.153698	56
5	.759492	3.00	.912922	1.48	.846570	4.48	.153430	55
6	.759672	3.00	.912833	1.48	.846839	4.48	.153161	54
7	.759852	2.98	.912744	1.48	.847108	4.47	.152892	53
8	.760031	3.00	.912655	1.48	.847376	4.47	.152624	52
9	.760211	2.98	.912566	1.48	.847644	4.48	.152356	51
10	.760390	2.98	.912477	1.48	.847913	4.47	.152087	50
11	9.760569	2.98	9.912388	1.48	9.848181	4.47	10.151819	49
12	.760748	2.98	.912299	1.48	.848449	4.47	.151551	48
13	.760927	2.98	.912210	1.48	.848717	4.48	.151283	47
14	.761106	2.98	.912121	1.50	.848986	4.47	.151014	46
15	.761285	2.98	.912031	1.48	.849254	4.47	.150746	45
16	.761464	2.97	.911942	1.48	.849522	4.47	.150478	44
17	.761642	2.98	.911853	1.50	.849790	4.45	.150210	43
18	.761821	2.97	.911763	1.48	.850057	4.47	.149943	42
19	.761999	2.97	.911674	1.50	.850325	4.47	.149675	41
20	.762177	2.98	.911584	1.48	.850593	4.47	.149407	40
21	9.762356	2.97	9.911495	1.50	9.850861	4.47	10.149139	39
22	.762534	2.97	.911405	1.50	.851129	4.45	.148871	38
23	.762712	2.95	.911315	1.48	.851396	4.47	.148604	37
24	.762889	2.97	.911226	1.50	.851664	4.45	.148336	36
25	.763067	2.97	.911136	1.50	.851931	4.47	.148069	35
26	.763245	2.95	.911046	1.50	.852199	4.45	.147801	34
27	.763422	2.97	.910956	1.50	.852466	4.45	.147534	33
28	.763600	2.95	.910866	1.50	.852733	4.47	.147267	32
29	.763777	2.95	.910776	1.50	.853001	4.45	.146999	31
30	.763954	2.95	.910686	1.50	.853268	4.45	.146732	30
31	9.764131	2.95	9.910596	1.50	9.853535	4.45	10.146465	29
32	.764308	2.95	.910506	1.52	.853802	4.45	.146198	28
33	.764485	2.95	.910415	1.50	.854069	4.45	.145931	27
34	.764662	2.93	.910325	1.50	.854336	4.45	.145664	26
35	.764838	2.95	.910235	1.52	.854603	4.45	.145397	25
36	.765015	2.93	.910144	1.50	.854870	4.45	.145130	24
37	.765191	2.93	.910054	1.52	.855137	4.45	.144863	23
38	.765367	2.95	.909963	1.50	.855404	4.45	.144596	22
39	.765544	2.93	.909873	1.52	.855671	4.45	.144329	21
40	.765720	2.93	.909782	1.52	.855938	4.43	.144062	20
41	9.765896	2.93	9.909691	1.50	9.856204	4.45	10.143796	19
42	.766072	2.92	.909601	1.52	.856471	4.43	.143529	18
43	.766247	2.93	.909510	1.52	.856737	4.45	.143263	17
44	.766423	2.92	.909419	1.52	.857004	4.43	.142996	16
45	.766598	2.93	.909328	1.52	.857270	4.45	.142730	15
46	.766774	2.92	.909237	1.52	.857537	4.43	.142463	14
47	.766949	2.92	.909146	1.52	.857803	4.43	.142197	13
48	.767124	2.93	.909055	1.52	.858069	4.45	.141931	12
49	.767300	2.92	.908964	1.52	.858336	4.43	.141664	11
50	.767475	2.90	.908873	1.53	.858602	4.43	.141398	10
51	9.767649	2.92	9.908781	1.52	9.858868	4.43	10.141132	9
52	.767824	2.92	.908690	1.52	.859134	4.43	.140866	8
53	.767999	2.90	.908599	1.53	.859400	4.43	.140600	7
54	.768173	2.92	.908507	1.52	.859666	4.43	.140334	6
55	.768348	2.90	.908416	1.53	.859932	4.43	.140068	5
56	.768522	2.92	.908324	1.52	.860198	4.43	.139802	4
57	.768697	2.90	.908233	1.53	.860464	4.43	.139536	3
58	.768871	2.90	.908141	1.53	.860730	4.42	.139270	2
59	.769045	2.90	.908049	1.52	.860995	4.43	.139005	1
60'	9.769219		9.907958		9.861261		10.138739	0'
125°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	54°

36°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang. 143°	
0'	9.769219	2.90	9.907958	1.53	9.861261	4.43	10.138739	60'
1	.769393	2.88	.907866	1.53	.861527	4.42	.138473	59
2	.769566	2.90	.907774	1.53	.861792	4.43	.138208	58
3	.769740	2.88	.907682	1.53	.862058	4.42	.137942	57
4	.769913	2.90	.907590	1.53	.862323	4.43	.137677	56
5	.770087	2.88	.907498	1.53	.862589	4.42	.137411	55
6	.770260	2.88	.907406	1.53	.862854	4.42	.137146	54
7	.770433	2.88	.907314	1.53	.863119	4.43	.136881	53
8	.770606	2.88	.907222	1.55	.863385	4.42	.136615	52
9	.770779	2.88	.907129	1.53	.863650	4.42	.136350	51
10	.770952	2.88	.907037	1.53	.863915	4.42	.136085	50
11	9.771125	2.88	9.906945	1.55	9.864180	4.42	10.135820	49
12	.771298	2.87	.906852	1.53	.864445	4.42	.135555	48
13	.771470	2.88	.906760	1.55	.864710	4.42	.135290	47
14	.771643	2.87	.906667	1.53	.864975	4.42	.135025	46
15	.771815	2.87	.906575	1.55	.865240	4.42	.134760	45
16	.771987	2.87	.906482	1.55	.865505	4.42	.134495	44
17	.772159	2.87	.906389	1.55	.865770	4.42	.134230	43
18	.772331	2.87	.906296	1.53	.866035	4.42	.133965	42
19	.772503	2.87	.906204	1.55	.866300	4.40	.133700	41
20	.772675	2.87	.906111	1.55	.866564	4.42	.133436	40
21	9.772847	2.85	9.906018	1.55	9.866829	4.42	10.133171	39
22	.773018	2.87	.905925	1.55	.867094	4.40	.132906	38
23	.773190	2.85	.905832	1.55	.867358	4.42	.132642	37
24	.773361	2.87	.905739	1.57	.867623	4.40	.132377	36
25	.773533	2.85	.905645	1.55	.867887	4.42	.132113	35
26	.773704	2.85	.905552	1.55	.868152	4.42	.131848	34
27	.773875	2.85	.905459	1.55	.868416	4.40	.131584	33
28	.774046	2.85	.905366	1.57	.868680	4.42	.131320	32
29	.774217	2.85	.905272	1.55	.868945	4.40	.131055	31
30	.774388	2.83	.905179	1.57	.869209	4.40	.130791	30
31	9.774558	2.85	9.905085	1.55	9.869473	4.40	10.130527	29
32	.774729	2.83	.904992	1.57	.869737	4.40	.130263	28
33	.774899	2.85	.904898	1.57	.870001	4.40	.129999	27
34	.775070	2.83	.904804	1.55	.870265	4.40	.129735	26
35	.775240	2.83	.904711	1.57	.870529	4.40	.129471	25
36	.775410	2.83	.904617	1.57	.870793	4.40	.129207	24
37	.775580	2.83	.904523	1.57	.871057	4.40	.128943	23
38	.775750	2.83	.904429	1.57	.871321	4.40	.128679	22
39	.775920	2.83	.904335	1.57	.871585	4.40	.128415	21
40	.776090	2.82	.904241	1.57	.871849	4.38	.128151	20
41	9.776259	2.83	9.904147	1.57	9.872112	4.40	10.127888	19
42	.776429	2.82	.904053	1.57	.872376	4.40	.127624	18
43	.776598	2.83	.903959	1.58	.872640	4.38	.127360	17
44	.776768	2.82	.903864	1.57	.872903	4.40	.127097	16
45	.776937	2.82	.903770	1.57	.873167	4.38	.126833	15
46	.777106	2.82	.903676	1.58	.873430	4.40	.126569	14
47	.777275	2.82	.903581	1.57	.873694	4.38	.126306	13
48	.777444	2.82	.903487	1.58	.873957	4.38	.126043	12
49	.777613	2.80	.903392	1.57	.874220	4.40	.125780	11
50	.777781	2.82	.903298	1.58	.874484	4.38	.125516	10
51	9.777950	2.82	9.903203	1.58	9.874747	4.38	10.125253	9
52	.778119	2.80	.903108	1.57	.875010	4.38	.124990	8
53	.778287	2.80	.903014	1.58	.875273	4.40	.124727	7
54	.778455	2.82	.902919	1.58	.875537	4.38	.124463	6
55	.778624	2.80	.902824	1.58	.875800	4.38	.124200	5
56	.778792	2.80	.902729	1.58	.876063	4.38	.123937	4
57	.778960	2.80	.902634	1.58	.876326	4.38	.123674	3
58	.779128	2.78	.902539	1.58	.876589	4.38	.123411	2
59	.779295	2.80	.902444	1.58	.876852	4.37	.123148	1
60'	9.779463		9.902349		9.877114		10.122886	0'
126°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	53°

37°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	142°
0'	9.779463	2.80	9.902349	1.60	9.877114	4.38	10.122886	60
1	.779631	2.78	.902258	1.58	.877377	4.38	.122623	59
2	.779798	2.80	.902158	1.58	.877640	4.38	.122360	58
3	.779966	2.78	.902068	1.60	.877903	4.37	.122097	57
4	.780133	2.78	.901967	1.58	.878165	4.38	.121835	56
5	.780300	2.78	.901872	1.60	.878428	4.38	.121572	55
6	.780467	2.78	.901775	1.58	.878691	4.37	.121309	54
7	.780634	2.78	.901681	1.60	.878953	4.38	.121047	53
8	.780801	2.78	.901585	1.58	.879216	4.37	.120784	52
9	.780968	2.77	.901490	1.60	.879478	4.38	.120522	51
10	.781134	2.78	.901394	1.60	.879741	4.37	.120259	50
11	9.781301	2.78	9.901298	1.60	9.880003	4.37	10.119997	49
12	.781468	2.77	.901202	1.60	.880265	4.38	.119735	48
13	.781634	2.77	.901106	1.60	.880528	4.37	.119472	47
14	.781800	2.77	.901010	1.60	.880790	4.37	.119210	46
15	.781966	2.77	.900914	1.60	.881052	4.37	.118948	45
16	.782132	2.77	.900818	1.60	.881314	4.38	.118686	44
17	.782298	2.77	.900722	1.60	.881577	4.37	.118423	43
18	.782464	2.77	.900626	1.62	.881839	4.37	.118161	42
19	.782630	2.77	.900529	1.60	.882101	4.37	.117899	41
20	.782796	2.75	.900433	1.60	.882363	4.37	.117637	40
21	9.782961	2.77	9.900337	1.62	9.882625	4.37	10.117375	39
22	.783127	2.75	.900240	1.60	.882887	4.35	.117113	38
23	.783292	2.77	.900144	1.62	.883148	4.37	.116852	37
24	.783458	2.75	.900047	1.60	.883410	4.37	.116590	36
25	.783623	2.75	.899951	1.62	.883672	4.37	.116328	35
26	.783788	2.75	.899854	1.62	.883934	4.37	.116066	34
27	.783953	2.75	.899757	1.62	.884196	4.37	.115804	33
28	.784118	2.75	.899660	1.62	.884457	4.35	.115543	32
29	.784282	2.73	.899564	1.60	.884719	4.37	.115281	31
30	.784447	2.75	.899467	1.62	.884980	4.35	.115020	30
31	9.784612	2.73	9.899370	1.62	9.885242	4.37	10.114758	29
32	.784776	2.75	.899273	1.62	.885504	4.35	.114496	28
33	.784941	2.73	.899176	1.63	.885765	4.35	.114235	27
34	.785105	2.73	.899078	1.62	.886026	4.35	.113974	26
35	.785269	2.73	.898981	1.62	.886288	4.37	.113712	25
36	.785433	2.73	.898884	1.62	.886549	4.35	.113451	24
37	.785597	2.73	.898787	1.62	.886811	4.37	.113189	23
38	.785761	2.73	.898689	1.63	.887072	4.35	.112928	22
39	.785925	2.73	.898592	1.63	.887333	4.35	.112667	21
40	.786089	2.72	.898494	1.62	.887594	4.35	.112406	20
41	9.786252	2.73	9.898397	1.63	9.887855	4.35	10.112145	19
42	.786416	2.72	.898299	1.62	.888116	4.37	.111884	18
43	.786579	2.72	.898202	1.63	.888378	4.35	.111622	17
44	.786742	2.73	.898104	1.63	.888639	4.35	.111361	16
45	.786906	2.72	.898006	1.63	.888900	4.35	.111100	15
46	.787069	2.72	.897908	1.63	.889161	4.33	.110839	14
47	.787232	2.72	.897810	1.63	.889421	4.35	.110579	13
48	.787395	2.70	.897712	1.63	.889682	4.35	.110318	12
49	.787557	2.72	.897614	1.63	.889943	4.35	.110057	11
50	.787720	2.72	.897516	1.63	.890204	4.35	.109796	10
51	9.787883	2.70	9.897418	1.63	9.890465	4.33	10.109535	9
52	.788045	2.72	.897320	1.63	.890725	4.35	.109275	8
53	.788208	2.70	.897222	1.65	.890986	4.35	.109014	7
54	.788370	2.70	.897123	1.63	.891247	4.33	.108753	6
55	.788532	2.70	.897025	1.65	.891507	4.35	.108493	5
56	.788694	2.70	.896926	1.63	.891768	4.33	.108232	4
57	.788856	2.70	.896828	1.65	.892028	4.35	.107972	3
58	.789018	2.70	.896729	1.63	.892289	4.33	.107711	2
59	.789180	2.70	.896631	1.65	.892549	4.35	.107451	1
60'	9.789342	2.70	9.896532	1.65	9.892810	4.35	10.107190	0

127°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	52°
------	---------	--------	-------	--------	---------	--------	-------	-----

38°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 141°	
0'	9.789342	2.70	9.896532	1.65	9.892810	4.33	10.107190	60'
1	.789504	2.68	.896433	1.63	.893070	4.35	.106930	59
2	.789665	2.70	.896335	1.65	.893331	4.33	.106669	58
3	.789827	2.68	.896236	1.65	.893591	4.33	.106409	57
4	.789988	2.68	.896137	1.65	.893851	4.33	.106149	56
5	.790149	2.68	.896038	1.65	.894111	4.33	.105889	55
6	.790310	2.68	.895939	1.65	.894372	4.33	.105628	54
7	.790471	2.68	.895840	1.65	.894632	4.33	.105368	53
8	.790632	2.68	.895741	1.67	.894892	4.33	.105108	52
9	.790793	2.68	.895641	1.65	.895152	4.33	.104848	51
10	.790954	2.68	.895542	1.65	.895412	4.33	.104588	50
11	9.791115	2.67	9.895443	1.67	9.895672	4.33	10.104328	49
12	.791275	2.65	.895343	1.65	.895932	4.33	.104068	48
13	.791436	2.67	.895244	1.65	.896192	4.33	.103808	47
14	.791596	2.68	.895145	1.67	.896452	4.33	.103548	46
15	.791757	2.67	.895045	1.67	.896712	4.33	.103288	45
16	.791917	2.67	.894945	1.65	.896971	4.33	.103029	44
17	.792077	2.67	.894846	1.67	.897231	4.33	.102769	43
18	.792237	2.67	.894746	1.67	.897491	4.33	.102509	42
19	.792397	2.67	.894646	1.67	.897751	4.32	.102249	41
20	.792557	2.65	.894546	1.67	.898010	4.33	.101990	40
21	9.792716	2.67	9.894446	1.67	9.898270	4.33	10.101730	39
22	.792876	2.65	.894346	1.67	.898530	4.32	.101470	38
23	.793035	2.67	.894246	1.67	.898789	4.33	.101211	37
24	.793195	2.65	.894146	1.67	.899049	4.32	.100951	36
25	.793354	2.67	.894046	1.67	.899308	4.33	.100692	35
26	.793514	2.65	.893946	1.67	.899568	4.32	.100432	34
27	.793673	2.65	.893846	1.67	.899827	4.33	.100173	33
28	.793832	2.65	.893745	1.67	.900087	4.32	.099913	32
29	.793991	2.65	.893645	1.68	.900346	4.32	.099654	31
30	.794150	2.63	.893544	1.67	.900605	4.32	.099395	30
31	9.794308	2.65	9.893444	1.68	9.900864	4.33	10.099136	29
32	.794467	2.65	.893343	1.67	.901124	4.32	.098876	28
33	.794626	2.63	.893243	1.68	.901383	4.32	.098617	27
34	.794784	2.63	.893142	1.68	.901642	4.32	.098358	26
35	.794942	2.65	.893041	1.68	.901901	4.32	.098099	25
36	.795101	2.63	.892940	1.68	.902160	4.33	.097840	24
37	.795259	2.63	.892839	1.67	.902420	4.32	.097580	23
38	.795417	2.63	.892739	1.68	.902679	4.32	.097321	22
39	.795575	2.63	.892638	1.70	.902938	4.32	.097062	21
40	.795733	2.63	.892536	1.68	.903197	4.32	.096803	20
41	9.795891	2.63	9.892435	1.68	9.903456	4.30	10.096544	19
42	.796049	2.62	.892334	1.68	.903714	4.32	.096286	18
43	.796206	2.63	.892233	1.68	.903973	4.32	.096027	17
44	.796364	2.62	.892132	1.70	.904232	4.32	.095768	16
45	.796521	2.63	.892030	1.68	.904491	4.32	.095509	15
46	.796679	2.62	.891929	1.70	.904750	4.30	.095250	14
47	.796836	2.62	.891827	1.68	.905008	4.32	.094992	13
48	.796993	2.62	.891726	1.70	.905267	4.32	.094733	12
49	.797150	2.62	.891624	1.68	.905526	4.32	.094474	11
50	.797307	2.62	.891523	1.70	.905785	4.30	.094215	10
51	9.797464	2.62	9.891421	1.70	9.906043	4.32	10.093957	9
52	.797621	2.60	.891319	1.70	.906302	4.30	.093698	8
53	.797777	2.62	.891217	1.70	.906560	4.32	.093440	7
54	.797934	2.62	.891115	1.70	.906819	4.30	.093181	6
55	.798091	2.60	.891013	1.70	.907077	4.32	.092923	5
56	.798247	2.60	.890911	1.70	.907336	4.30	.092664	4
57	.798403	2.62	.890809	1.70	.907594	4.32	.092406	3
58	.798560	2.60	.890707	1.70	.907853	4.30	.092147	2
59	.798716	2.60	.890605	1.70	.908111	4.30	.091889	1
60'	9.798872	2.60	9.890503	1.70	9.908369	4.30	10.091631	0'
128°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	51°

39°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	140°
0'	9.798872	2.60	9.890503	1.72	9.908369	4.32	10.091621	60'
1	.799028	2.60	.890400	1.70	.908628	4.30	.091372	59
2	.799184	2.58	.890298	1.72	.908886	4.30	.091114	58
3	.799339	2.60	.890195	1.70	.909144	4.30	.090856	57
4	.799495	2.60	.890093	1.72	.909402	4.30	.090598	56
5	.799651	2.58	.889990	1.70	.909660	4.30	.090340	55
6	.799806	2.60	.889888	1.72	.909918	4.30	.090082	54
7	.799962	2.58	.889785	1.72	.910177	4.32	.089823	53
8	.800117	2.58	.889682	1.72	.910435	4.30	.089565	52
9	.800272	2.58	.889579	1.70	.910693	4.30	.089307	51
10	.800427	2.58	.889477	1.72	.910951	4.30	.089049	50
11	9.800582	2.58	9.889374	1.72	9.911209	4.30	10.088791	49
12	.800737	2.58	.889271	1.72	.911467	4.30	.088533	48
13	.800892	2.58	.889168	1.73	.911725	4.28	.088275	47
14	.801047	2.57	.889064	1.72	.911982	4.30	.088018	46
15	.801201	2.58	.888961	1.72	.912240	4.30	.087760	45
16	.801356	2.58	.888858	1.72	.912498	4.30	.087502	44
17	.801511	2.57	.888755	1.73	.912756	4.30	.087244	43
18	.801665	2.57	.888651	1.72	.913014	4.30	.086986	42
19	.801819	2.57	.888548	1.73	.913271	4.28	.086729	41
20	.801973	2.58	.888444	1.72	.913529	4.30	.086471	40
21	9.802128	2.57	9.888341	1.73	9.913787	4.28	10.086213	39
22	.802282	2.57	.888237	1.72	.914044	4.30	.085956	38
23	.802436	2.55	.888134	1.73	.914302	4.30	.085698	37
24	.802589	2.57	.888030	1.73	.914560	4.28	.085440	36
25	.802743	2.57	.887926	1.73	.914817	4.30	.085183	35
26	.802897	2.55	.887822	1.73	.915075	4.28	.084925	34
27	.803050	2.57	.887718	1.73	.915332	4.30	.084668	33
28	.803204	2.55	.887614	1.73	.915590	4.28	.084410	32
29	.803357	2.57	.887510	1.73	.915847	4.28	.084153	31
30	.803511	2.56	.887406	1.73	.916104	4.30	.083896	30
31	9.803664	2.55	9.887302	1.73	9.916362	4.28	10.083638	29
32	.803817	2.55	.887198	1.75	.916619	4.30	.083381	28
33	.803970	2.55	.887093	1.73	.916877	4.28	.083123	27
34	.804123	2.55	.886989	1.73	.917134	4.28	.082866	26
35	.804276	2.55	.886885	1.75	.917391	4.28	.082609	25
36	.804428	2.55	.886780	1.73	.917648	4.30	.082352	24
37	.804581	2.55	.886676	1.75	.917906	4.28	.082094	23
38	.804734	2.53	.886571	1.75	.918163	4.28	.081837	22
39	.804886	2.55	.886466	1.73	.918420	4.28	.081580	21
40	.805039	2.53	.886362	1.75	.918677	4.28	.081323	20
41	9.805191	2.53	9.886257	1.75	9.918934	4.28	10.081066	19
42	.805343	2.53	.886152	1.75	.919191	4.28	.080809	18
43	.805495	2.53	.886047	1.75	.919448	4.28	.080552	17
44	.805647	2.53	.885942	1.75	.919705	4.28	.080295	16
45	.805799	2.53	.885837	1.75	.919962	4.28	.080038	15
46	.805951	2.53	.885732	1.75	.920219	4.28	.079781	14
47	.806103	2.52	.885627	1.75	.920476	4.28	.079524	13
48	.806254	2.53	.885522	1.77	.920733	4.28	.079267	12
49	.806406	2.52	.885416	1.75	.920990	4.28	.079010	11
50	.806557	2.53	.885311	1.77	.921247	4.27	.078753	10
51	9.806709	2.52	9.885205	1.75	9.921503	4.28	10.078497	9
52	.806860	2.52	.885100	1.77	.921760	4.28	.078240	8
53	.807011	2.53	.884994	1.75	.922017	4.28	.077983	7
54	.807163	2.52	.884889	1.77	.922274	4.27	.077726	6
55	.807314	2.52	.884783	1.77	.922530	4.28	.077470	5
56	.807465	2.50	.884677	1.75	.922787	4.28	.077213	4
57	.807615	2.52	.884572	1.77	.923044	4.27	.076956	3
58	.807766	2.52	.884466	1.77	.923300	4.28	.076700	2
59	.807917	2.50	.884360	1.77	.923557	4.28	.076443	1
60'	9.808067	2.50	9.884254	1.77	9.923814	4.28	10.076186	0'
129° Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	50°	

40°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang.	139°
0'	9.808067	2.52	9.884254	1.77	9.923814	4.27	10.076186	60'
1	.808218	2.50	.884148	1.77	.924070	4.28	.075980	59
2	.808368	2.52	.884042	1.77	.924327	4.27	.075673	58
3	.808519	2.50	.883936	1.78	.924583	4.27	.075417	57
4	.808669	2.50	.883829	1.77	.924840	4.28	.075160	56
5	.808819	2.50	.883723	1.77	.925096	4.27	.074904	55
6	.808969	2.50	.883617	1.78	.925352	4.28	.074648	54
7	.809119	2.50	.883510	1.77	.925609	4.27	.074391	53
8	.809269	2.50	.883404	1.78	.925865	4.28	.074135	52
9	.809419	2.50	.883297	1.77	.926122	4.27	.073878	51
10	.809569	2.48	.883191	1.78	.926378	4.27	.073622	50
11	9.809718	2.50	9.883084	1.78	9.926634	4.27	10.073366	49
12	.809868	2.48	.882977	1.77	.926890	4.28	.073110	48
13	.810017	2.50	.882871	1.78	.927147	4.27	.072853	47
14	.810167	2.48	.882764	1.78	.927403	4.27	.072597	46
15	.810316	2.48	.882657	1.78	.927659	4.27	.072341	45
16	.810465	2.48	.882550	1.78	.927915	4.27	.072085	44
17	.810614	2.48	.882443	1.78	.928171	4.27	.071829	43
18	.810763	2.48	.882336	1.78	.928427	4.28	.071573	42
19	.810912	2.48	.882229	1.80	.928684	4.27	.071316	41
20	.811061	2.48	.882121	1.78	.928940	4.27	.071060	40
21	9.811210	2.47	9.882014	1.78	9.929196	4.27	10.070804	39
22	.811358	2.48	.881907	1.80	.929452	4.27	.070548	38
23	.811507	2.47	.881799	1.78	.929708	4.27	.070292	37
24	.811655	2.48	.881692	1.80	.929964	4.27	.070036	36
25	.811804	2.47	.881584	1.78	.930220	4.25	.069780	35
26	.811952	2.47	.881477	1.80	.930475	4.27	.069525	34
27	.812100	2.47	.881369	1.80	.930731	4.27	.069269	33
28	.812248	2.47	.881261	1.80	.930987	4.27	.069013	32
29	.812396	2.47	.881153	1.78	.931243	4.27	.068757	31
30	.812544	2.47	.881046	1.80	.931499	4.27	.068501	30
31	9.812692	2.47	9.880938	1.80	9.931755	4.25	10.068245	29
32	.812840	2.47	.880830	1.80	.932010	4.27	.067990	28
33	.812988	2.45	.880722	1.82	.932266	4.27	.067734	27
34	.813135	2.47	.880613	1.80	.932522	4.27	.067478	26
35	.813283	2.45	.880505	1.80	.932778	4.25	.067222	25
36	.813430	2.47	.880397	1.80	.933033	4.27	.066967	24
37	.813578	2.45	.880289	1.82	.933289	4.27	.066711	23
38	.813725	2.45	.880180	1.80	.933545	4.25	.066455	22
39	.813872	2.45	.880072	1.82	.933800	4.27	.066200	21
40	.814019	2.45	.879963	1.80	.934056	4.25	.065944	20
41	9.814166	2.45	9.879855	1.82	9.934311	4.27	10.065689	19
42	.814313	2.45	.879746	1.82	.934567	4.25	.065433	18
43	.814460	2.45	.879637	1.80	.934822	4.27	.065178	17
44	.814607	2.43	.879529	1.82	.935078	4.25	.064922	16
45	.814753	2.45	.879420	1.82	.935333	4.27	.064667	15
46	.814900	2.43	.879311	1.82	.935589	4.25	.064411	14
47	.815046	2.45	.879202	1.82	.935844	4.27	.064156	13
48	.815193	2.43	.879093	1.82	.936100	4.25	.063900	12
49	.815339	2.43	.878984	1.82	.936355	4.27	.063645	11
50	.815485	2.45	.878875	1.82	.936611	4.25	.063389	10
51	9.815632	2.43	9.878766	1.83	9.936866	4.25	10.063134	9
52	.815778	2.43	.878656	1.82	.937121	4.27	.062879	8
53	.815924	2.42	.878547	1.82	.937377	4.25	.062623	7
54	.816069	2.43	.878438	1.83	.937632	4.25	.062368	6
55	.816215	2.43	.878328	1.82	.937887	4.25	.062113	5
56	.816361	2.43	.878219	1.83	.938142	4.27	.061858	4
57	.816507	2.42	.878109	1.83	.938398	4.25	.061602	3
58	.816652	2.43	.877999	1.82	.938653	4.25	.061347	2
59	.816798	2.42	.877890	1.83	.938908	4.25	.061092	1
60	9.816943		9.877780		9.939163		10.060837	0'
130°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	49°

41°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 138°	
0	9.816943		9.877780		9.939163		10.060837	60
1	.817088	2.42	.877670	1.83	.939418	4.25	.060582	59
2	.817233	2.42	.877560	1.83	.939673	4.25	.060327	58
3	.817379	2.43	.877450	1.83	.939928	4.25	.060072	57
4	.817524	2.42	.877340	1.83	.940183	4.25	.059817	56
5	.817668	2.40	.877230	1.83	.940439	4.27	.059561	55
6	.817813	2.42	.877120	1.83	.940694	4.25	.059306	54
7	.817958	2.42	.877010	1.83	.940949	4.25	.059051	53
8	.818103	2.42	.876899	1.85	.941204	4.25	.058796	52
9	.818247	2.40	.876789	1.83	.941459	4.25	.058541	51
10	.818392	2.42	.876678	1.85	.941713	4.23	.058287	50
		2.40		1.83		4.25		
11	9.818536		9.876568		9.941968		10.058032	49
12	.818681	2.42	.876457	1.85	.942223	4.25	.057777	48
13	.818825	2.40	.876347	1.83	.942478	4.25	.057522	47
14	.818969	2.40	.876236	1.85	.942733	4.25	.057267	46
15	.819113	2.40	.876125	1.85	.942988	4.25	.057012	45
16	.819257	2.40	.876014	1.85	.943243	4.25	.056757	44
17	.819401	2.40	.875904	1.83	.943498	4.25	.056502	43
18	.819545	2.40	.875793	1.85	.943752	4.23	.056248	42
19	.819689	2.40	.875682	1.85	.944007	4.25	.055993	41
20	.819832	2.38	.875571	1.85	.944262	4.25	.055738	40
		2.40		1.87		4.25		
21	9.819976		9.875459		9.944517		10.055483	39
22	.820120	2.40	.875348	1.85	.944771	4.23	.055229	38
23	.820263	2.38	.875237	1.85	.945026	4.25	.054974	37
24	.820406	2.38	.875126	1.85	.945281	4.25	.054719	36
25	.820550	2.40	.875014	1.87	.945535	4.23	.054465	35
26	.820693	2.38	.874903	1.85	.945790	4.25	.054210	34
27	.820836	2.38	.874791	1.87	.946045	4.25	.053955	33
28	.820979	2.38	.874680	1.85	.946299	4.23	.053701	32
29	.821122	2.38	.874568	1.87	.946554	4.25	.053446	31
30	.821265	2.38	.874456	1.87	.946808	4.23	.053192	30
		2.37		1.87		4.25		
31	9.821407		9.874344		9.947063		10.052937	29
32	.821550	2.38	.874232	1.87	.947318	4.25	.052682	28
33	.821693	2.38	.874121	1.85	.947572	4.23	.052428	27
34	.821835	2.37	.874009	1.87	.947827	4.25	.052173	26
35	.821977	2.37	.873896	1.88	.948081	4.23	.051919	25
36	.822120	2.38	.873784	1.87	.948335	4.23	.051665	24
37	.822262	2.37	.873672	1.87	.948590	4.25	.051410	23
38	.822404	2.37	.873560	1.87	.948844	4.23	.051156	22
39	.822546	2.37	.873448	1.87	.949099	4.25	.050901	21
40	.822688	2.37	.873335	1.88	.949353	4.23	.050647	20
		2.37		1.87		4.25		
41	9.822830		9.873223		9.949608		10.050392	19
42	.822972	2.37	.873110	1.88	.949862	4.23	.050138	18
43	.823114	2.37	.872998	1.87	.950116	4.23	.049884	17
44	.823255	2.35	.872885	1.88	.950371	4.25	.049629	16
45	.823397	2.37	.872772	1.88	.950625	4.23	.049375	15
46	.823539	2.37	.872659	1.88	.950879	4.23	.049121	14
47	.823680	2.35	.872547	1.87	.951133	4.23	.048867	13
48	.823821	2.35	.872434	1.88	.951388	4.25	.048612	12
49	.823963	2.37	.872321	1.88	.951642	4.23	.048358	11
50	.824104	2.35	.872208	1.88	.951896	4.23	.048104	10
		2.35		1.88		4.23		
51	9.824245		9.872095		9.952150		10.047850	9
52	.824386	2.35	.871981	1.90	.952405	4.25	.047595	8
53	.824527	2.35	.871868	1.88	.952659	4.23	.047341	7
54	.824668	2.35	.871755	1.88	.952913	4.23	.047087	6
55	.824808	2.33	.871641	1.90	.953167	4.23	.046833	5
56	.824949	2.35	.871528	1.88	.953421	4.23	.046579	4
57	.825090	2.35	.871414	1.90	.953675	4.23	.046325	3
58	.825230	2.33	.871301	1.88	.953929	4.23	.046071	2
59	.825371	2.35	.871187	1.90	.954183	4.23	.045817	1
60'	9.825511		9.871073		9.954437		10.045563	0'
		2.33		1.90		4.23		

131°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	48°
------	---------	--------	-------	--------	---------	--------	-------	-----

42°	Sine.	D. 1'.	Cosine.	D. 1'.	Tang.	D. 1'.	Cotang. 137°	
0'	9.825511	2.33	9.871073	1.88	9.954437	4.23	10.045563	60'
1	.825651	2.33	.870960	1.90	.954691	4.25	.045309	59
2	.825791	2.33	.870846	1.90	.954946	4.23	.045054	58
3	.825931	2.33	.870732	1.90	.955200	4.23	.044800	57
4	.826071	2.33	.870618	1.90	.955454	4.23	.044546	56
5	.826211	2.33	.870504	1.90	.955708	4.23	.044292	55
6	.826351	2.33	.870390	1.90	.955961	4.22	.044039	54
7	.826491	2.33	.870276	1.90	.956215	4.23	.043785	53
8	.826631	2.32	.870161	1.92	.956469	4.23	.043531	52
9	.826770	2.33	.870047	1.90	.956723	4.23	.043277	51
10	.826910	2.32	.869933	1.92	.956977	4.23	.043023	50
11	9.827049	2.33	9.869818	1.90	9.957231	4.23	10.042769	49
12	.827189	2.32	.869704	1.92	.957485	4.23	.042515	48
13	.827328	2.32	.869589	1.92	.957739	4.23	.042261	47
14	.827467	2.32	.869474	1.92	.957993	4.23	.042007	46
15	.827606	2.32	.869360	1.92	.958247	4.23	.041753	45
16	.827745	2.32	.869245	1.92	.958500	4.22	.041500	44
17	.827884	2.32	.869130	1.92	.958754	4.23	.041246	43
18	.828023	2.32	.869015	1.92	.959008	4.23	.040992	42
19	.828162	2.32	.868900	1.92	.959262	4.23	.040738	41
20	.828301	2.30	.868785	1.92	.959516	4.22	.040484	40
21	9.828439	2.32	9.868670	1.92	9.959769	4.23	10.040231	39
22	.828578	2.30	.868555	1.92	.960023	4.23	.039977	38
23	.828716	2.32	.868440	1.93	.960277	4.22	.039723	37
24	.828855	2.30	.868324	1.92	.960530	4.23	.039470	36
25	.828993	2.30	.868209	1.93	.960784	4.23	.039216	35
26	.829131	2.30	.868093	1.93	.961038	4.23	.038962	34
27	.829269	2.30	.867978	1.93	.961292	4.23	.038708	33
28	.829407	2.30	.867862	1.92	.961545	4.23	.038455	32
29	.829545	2.30	.867747	1.93	.961799	4.22	.038201	31
30	.829683	2.30	.867631	1.93	.962052	4.23	.037948	30
31	9.829821	2.30	9.867515	1.93	9.962306	4.23	10.037694	29
32	.829959	2.30	.867399	1.93	.962560	4.22	.037440	28
33	.830097	2.28	.867283	1.93	.962813	4.23	.037187	27
34	.830234	2.30	.867167	1.93	.963067	4.22	.036933	26
35	.830372	2.28	.867051	1.93	.963320	4.23	.036680	25
36	.830509	2.28	.866935	1.93	.963574	4.23	.036426	24
37	.830646	2.30	.866819	1.93	.963828	4.23	.036172	23
38	.830784	2.28	.866703	1.95	.964081	4.23	.035919	22
39	.830921	2.28	.866586	1.93	.964335	4.22	.035665	21
40	.831058	2.28	.866470	1.95	.964588	4.23	.035412	20
41	9.831195	2.28	9.866353	1.93	9.964842	4.22	10.035158	19
42	.831332	2.28	.866237	1.95	.965095	4.23	.034905	18
43	.831469	2.28	.866120	1.93	.965349	4.22	.034651	17
44	.831606	2.27	.866004	1.95	.965602	4.22	.034398	16
45	.831742	2.28	.865887	1.95	.965855	4.23	.034145	15
46	.831879	2.27	.865770	1.95	.966109	4.22	.033891	14
47	.832015	2.28	.865653	1.95	.966362	4.23	.033638	13
48	.832152	2.27	.865536	1.95	.966616	4.22	.033384	12
49	.832288	2.28	.865419	1.95	.966869	4.23	.033131	11
50	.832425	2.27	.865302	1.95	.967123	4.22	.032877	10
51	9.832561	2.27	9.865185	1.95	9.967376	4.22	10.032624	9
52	.832697	2.27	.865068	1.97	.967629	4.23	.032371	8
53	.832833	2.27	.864950	1.95	.967883	4.22	.032117	7
54	.832969	2.27	.864833	1.95	.968136	4.22	.031864	6
55	.833105	2.27	.864716	1.97	.968389	4.23	.031611	5
56	.833241	2.27	.864598	1.95	.968643	4.22	.031357	4
57	.833377	2.25	.864481	1.97	.968896	4.22	.031104	3
58	.833512	2.27	.864363	1.97	.969149	4.23	.030851	2
59	.833648	2.25	.864245	1.97	.969403	4.22	.030597	1
60'	9.833783		9.864127		9.969656		10.030344	0'

132°	Cosine.	D. 1'.	Sine.	D. 1'.	Cotang.	D. 1'.	Tang.	47°
------	---------	--------	-------	--------	---------	--------	-------	-----

43°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	136°
0'	9.833783		9.864127		9.969656		10.030344	60'
1	.833919	2.27	.864010	1.95	.969909	4.22	.030091	59
2	.834054	2.25	.863892	1.97	.970162	4.22	.029838	58
3	.834189	2.25	.863774	1.97	.970416	4.23	.029584	57
4	.834325	2.27	.863656	1.97	.970669	4.22	.029331	56
5	.834460	2.25	.863538	1.97	.970922	4.22	.029078	55
6	.834595	2.25	.863419	1.98	.971175	4.22	.028825	54
7	.834730	2.25	.863301	1.97	.971429	4.23	.028571	53
8	.834865	2.25	.863183	1.97	.971682	4.22	.028318	52
9	.834999	2.23	.863064	1.98	.971935	4.22	.028065	51
10	.835134	2.25	.862946	1.97	.972188	4.22	.027812	50
11	9.835269		9.862827		9.972441		10.027559	49
12	.835403	2.23	.862709	1.97	.972695	4.23	.027305	48
13	.835538	2.25	.862590	1.98	.972948	4.22	.027052	47
14	.835672	2.23	.862471	1.98	.973201	4.22	.026799	46
15	.835807	2.25	.862353	1.97	.973454	4.22	.026546	45
16	.835941	2.23	.862234	1.98	.973707	4.22	.026293	44
17	.836075	2.23	.862115	1.98	.973960	4.22	.026040	43
18	.836209	2.23	.861996	1.98	.974213	4.22	.025787	42
19	.836343	2.23	.861877	1.98	.974466	4.22	.025534	41
20	.836477	2.23	.861758	2.00	.974720	4.22	.025280	40
21	9.836611		9.861638		9.974973		10.025027	39
22	.836745	2.22	.861519	1.98	.975226	4.22	.024774	38
23	.836878	2.22	.861400	1.98	.975479	4.22	.024521	37
24	.837012	2.23	.861280	2.00	.975732	4.22	.024268	36
25	.837146	2.22	.861161	1.98	.975985	4.22	.024015	35
26	.837279	2.22	.861041	2.00	.976238	4.22	.023762	34
27	.837412	2.22	.860922	1.98	.976491	4.22	.023509	33
28	.837546	2.23	.860802	2.00	.976744	4.22	.023256	32
29	.837679	2.22	.860682	2.00	.976997	4.22	.023003	31
30	.837812	2.22	.860562	2.00	.977250	4.22	.022750	30
31	9.837045		9.860442		9.977503		10.022497	29
32	.838078	2.22	.860322	2.00	.977756	4.22	.022244	28
33	.838211	2.22	.860202	2.00	.978009	4.22	.021991	27
34	.838344	2.22	.860082	2.00	.978262	4.22	.021738	26
35	.838477	2.22	.859962	2.00	.978515	4.22	.021485	25
36	.838610	2.22	.859842	2.00	.978768	4.22	.021232	24
37	.838742	2.20	.859721	2.02	.979021	4.22	.020979	23
38	.838875	2.22	.859601	2.00	.979274	4.22	.020726	22
39	.839007	2.22	.859480	2.02	.979527	4.22	.020473	21
40	.839140	2.20	.859360	2.02	.979780	4.22	.020220	20
41	9.839272		9.859239		9.980033		10.019967	19
42	.839404	2.20	.859119	2.00	.980286	4.22	.019714	18
43	.839536	2.20	.858998	2.02	.980538	4.20	.019462	17
44	.839668	2.20	.858877	2.02	.980791	4.22	.019209	16
45	.839800	2.20	.858756	2.02	.981044	4.22	.018956	15
46	.839932	2.20	.858635	2.02	.981297	4.22	.018703	14
47	.840064	2.20	.858514	2.02	.981550	4.22	.018450	13
48	.840196	2.20	.858393	2.02	.981803	4.22	.018197	12
49	.840328	2.18	.858272	2.02	.982056	4.22	.017944	11
50	.840459	2.20	.858151	2.03	.982309	4.22	.017691	10
51	9.840591		9.858029		9.982562		10.017438	9
52	.840722	2.18	.857908	2.02	.982814	4.20	.017186	8
53	.840854	2.20	.857786	2.03	.983067	4.22	.016933	7
54	.840985	2.18	.857665	2.02	.983320	4.22	.016680	6
55	.841116	2.18	.857543	2.03	.983573	4.22	.016427	5
56	.841247	2.18	.857422	2.02	.983826	4.22	.016174	4
57	.841378	2.18	.857300	2.03	.984079	4.22	.015921	3
58	.841509	2.18	.857178	2.03	.984332	4.22	.015668	2
59	.841640	2.18	.857056	2.03	.984584	4.20	.015416	1
60'	9.841771		9.856934		9.984837		10.015163	0'
133° Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	46°	

44°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	135°
0'	9.841771	2.18	9.856934	2.03	9.984837	4.22	10.015163	60
1	.841902	2.18	.856812	2.03	.985090	4.22	.014910	59
2	.842033	2.17	.856690	2.03	.985343	4.22	.014657	58
3	.842163	2.18	.856568	2.03	.985596	4.22	.014404	57
4	.842294	2.17	.856446	2.05	.985848	4.22	.014152	56
5	.842424	2.18	.856323	2.03	.986101	4.22	.013899	55
6	.842555	2.17	.856201	2.05	.986354	4.22	.013646	54
7	.842685	2.17	.856078	2.03	.986607	4.22	.013393	53
8	.842815	2.18	.855956	2.05	.986860	4.22	.013140	52
9	.842946	2.17	.855833	2.03	.987112	4.22	.012888	51
10	.843076	2.17	.855711	2.05	.987365	4.22	.012635	50
11	9.843206	2.17	9.855588	2.05	9.987618	4.22	10.012382	49
12	.843336	2.17	.855465	2.05	.987871	4.22	.012129	48
13	.843466	2.15	.855342	2.05	.988123	4.22	.011877	47
14	.843595	2.17	.855219	2.05	.988376	4.22	.011624	46
15	.843725	2.17	.855096	2.05	.988629	4.22	.011371	45
16	.843855	2.15	.854973	2.05	.988882	4.22	.011118	44
17	.843984	2.17	.854850	2.05	.989134	4.22	.010866	43
18	.844114	2.15	.854727	2.07	.989387	4.22	.010613	42
19	.844243	2.15	.854603	2.05	.989640	4.22	.010360	41
20	.844372	2.17	.854480	2.07	.989893	4.22	.010107	40
21	9.844502	2.15	9.854356	2.05	9.990145	4.22	10.009855	39
22	.844631	2.15	.854233	2.07	.990398	4.22	.009602	38
23	.844760	2.15	.854109	2.05	.990651	4.22	.009349	37
24	.844889	2.15	.853986	2.07	.990903	4.22	.009097	36
25	.845018	2.15	.853862	2.07	.991156	4.22	.008844	35
26	.845147	2.15	.853738	2.07	.991409	4.22	.008591	34
27	.845276	2.15	.853614	2.07	.991662	4.22	.008338	33
28	.845405	2.13	.853490	2.07	.991914	4.22	.008086	32
29	.845533	2.15	.853366	2.07	.992167	4.22	.007833	31
30	.845662	2.13	.853242	2.07	.992420	4.22	.007580	30
31	9.845790	2.15	9.853118	2.07	9.992672	4.22	10.007328	29
32	.845919	2.13	.852994	2.08	.992925	4.22	.007075	28
33	.846047	2.13	.852869	2.07	.993178	4.22	.006822	27
34	.846175	2.15	.852745	2.08	.993431	4.22	.006569	26
35	.846304	2.13	.852620	2.07	.993683	4.22	.006317	25
36	.846432	2.13	.852496	2.08	.993936	4.22	.006064	24
37	.846560	2.13	.852371	2.07	.994189	4.22	.005811	23
38	.846688	2.13	.852247	2.08	.994441	4.22	.005559	22
39	.846816	2.13	.852122	2.08	.994694	4.22	.005306	21
40	.846944	2.12	.851997	2.08	.994947	4.22	.005053	20
41	9.847071	2.13	9.851872	2.08	9.995199	4.22	10.004801	19
42	.847199	2.13	.851747	2.08	.995452	4.22	.004548	18
43	.847327	2.12	.851622	2.08	.995705	4.22	.004295	17
44	.847454	2.13	.851497	2.08	.995957	4.22	.004043	16
45	.847582	2.12	.851372	2.10	.996210	4.22	.003790	15
46	.847709	2.12	.851246	2.08	.996463	4.22	.003537	14
47	.847836	2.13	.851121	2.08	.996715	4.22	.003285	13
48	.847964	2.12	.850996	2.10	.996968	4.22	.003032	12
49	.848091	2.12	.850870	2.08	.997221	4.22	.002779	11
50	.848218	2.12	.850745	2.10	.997473	4.22	.002527	10
51	9.848345	2.12	9.850619	2.10	9.997726	4.22	10.002274	9
52	.848472	2.12	.850493	2.08	.997979	4.22	.002021	8
53	.848599	2.12	.850368	2.10	.998231	4.22	.001769	7
54	.848726	2.10	.850242	2.10	.998484	4.22	.001516	6
55	.848852	2.12	.850116	2.10	.998737	4.22	.001263	5
56	.848979	2.12	.849990	2.10	.998989	4.22	.001011	4
57	.849106	2.10	.849864	2.10	.999242	4.22	.000758	3
58	.849232	2.12	.849738	2.12	.999495	4.22	.000505	2
59	.849359	2.10	.849611	2.10	.999747	4.22	.000253	1
60'	9.849485		9.849485		10.000000		10.000000	0'
134°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1"	Tang.	45°

0°					1°						
"	'	Vers.	q - 2l		Ex. sec.	"	'	Vers.	q - 2l		Ex. sec.
9.070					9.070						
0	0	Inf. neg.	120	120	Inf. neg.	3600	0	6.182714	109	175	6.182780
60	1	2.626422	120	120	2.626422	3660	1	.197071	108	177	.197139
120	2	3.228482	120	120	3.228482	3720	2	.211194	108	179	.211264
180	3	.580665	120	120	.580665	3780	3	.225091	108	181	.225164
240	4	3.830542	120	120	3.830542	3840	4	.238770	107	182	.238845
300	5	4.024362	120	120	4.024363	3900	5	.252236	107	184	.252314
360	6	.182725	120	120	.182725	3960	6	.265497	106	186	.265577
420	7	.316618	120	120	.316619	4020	7	.278558	106	188	.278641
480	8	.432602	120	121	.432603	4080	8	.291426	106	191	.291511
540	9	.534907	119	121	.534908	4140	9	.304106	105	193	.304193
600	10	.626422	119	121	.626424	4200	10	.316603	105	195	.316693
660	11	4.709207	119	122	4.709209	4260	11	6.328923	104	197	6.329016
720	12	.784784	119	122	.784787	4320	12	.341071	104	199	.341167
780	13	.854308	119	122	.854312	4380	13	.353052	103	201	.353150
840	14	.918678	119	123	.918681	4440	14	.364869	103	204	.364970
900	15	4.978604	119	123	4.978608	4500	15	.376528	103	206	.376631
960	16	5.034661	119	124	5.034666	4560	16	.388032	102	208	.388138
1020	17	.087319	119	124	.087325	4620	17	.399386	102	211	.399494
1080	18	.136966	119	125	.136972	4680	18	.410593	101	213	.410705
1140	19	.183928	119	125	.183935	4740	19	.421657	101	215	.421772
1200	20	.228481	119	126	.228488	4800	20	.432583	100	218	.432700
1260	21	5.270859	118	126	5.270868	4860	21	6.443372	100	220	6.443493
1320	22	.311266	118	127	.311275	4920	22	.454029	099	223	.454153
1380	23	.349876	118	128	.349886	4980	23	.464557	099	225	.464684
1440	24	.386843	118	129	.386854	5040	24	.474959	098	228	.475089
1500	25	.422300	118	129	.422312	5100	25	.485238	098	230	.485371
1560	26	.456367	118	130	.456379	5160	26	.495396	097	233	.495532
1620	27	.489148	118	131	.489161	5220	27	.505438	097	236	.505577
1680	28	.520736	117	132	.520750	5280	28	.515364	096	238	.515506
1740	29	.551216	117	133	.551231	5340	29	.525178	095	241	.525324
1800	30	.580662	117	134	.580679	5400	30	.534882	095	244	.535031
1860	31	5.609148	117	134	5.609160	5460	31	6.544480	094	247	6.544632
1920	32	.636719	117	135	.636738	5520	32	.553972	094	249	.554128
1980	33	.663447	116	136	.663467	5580	33	.563362	093	252	.563521
2040	34	.689377	116	137	.689398	5640	34	.572651	093	255	.572813
2100	35	.714555	116	138	.714577	5700	35	.581842	092	258	.582008
2160	36	.739023	116	140	.739047	5760	36	.590936	092	261	.591106
2220	37	.762821	116	141	.762847	5820	37	.599937	091	264	.600110
2280	38	.785985	115	142	.786012	5880	38	.608845	090	267	.609021
2340	39	.808547	115	143	.808575	5940	39	.617663	090	270	.617843
2400	40	.830537	115	144	.830567	6000	40	.626392	089	273	.626575
2460	41	5.851985	115	145	5.852016	6060	41	6.635034	089	276	6.635221
2520	42	.872915	114	147	.872948	6120	42	.643591	088	279	.643782
2580	43	.893353	114	148	.893387	6180	43	.652064	087	282	.652259
2640	44	.913322	114	149	.913357	6240	44	.660456	087	285	.660655
2700	45	.932841	114	151	.932878	6300	45	.668767	086	289	.668970
2760	46	.951931	113	152	.951970	6360	46	.677000	085	292	.677206
2820	47	.970611	113	154	.970652	6420	47	.685155	085	295	.685365
2880	48	5.988898	113	155	5.988940	6480	48	.693234	084	298	.693448
2940	49	6.006807	112	157	6.006851	6540	49	.701239	083	302	.701457
3000	50	.024355	112	158	.024401	6600	50	.709171	083	305	.709393
3060	51	6.041555	112	160	6.041602	6660	51	6.717030	082	308	6.717257
3120	52	.058421	111	161	.058470	6720	52	.724820	081	312	.725050
3180	53	.074965	111	163	.075017	6780	53	.732540	081	315	.732775
3240	54	.091201	111	164	.091254	6840	54	.740192	080	319	.740431
3300	55	.107138	110	166	.107194	6900	55	.747777	079	322	.748020
3360	56	.122789	110	168	.122846	6960	56	.755297	079	326	.755544
3420	57	.138162	110	169	.138222	7020	57	.762752	078	329	.763004
3480	58	.153268	109	171	.153330	7080	58	.770144	077	333	.770400
3540	59	.168116	109	173	.168180	7140	59	.777473	076	337	.777733
3600	60	6.182714	109	175	6.182780	7200	60	6.784741	076	340	6.785006

2°

"	'	Vers.	q - 2l		Ex. sec.
			9.070		
7200	0	6.784741	076	340	6.785005
7260	1	.791948	075	344	.792217
7320	2	.799096	074	348	.799370
7380	3	.806186	073	351	.806464
7440	4	.813219	073	355	.813501
7500	5	.820194	072	359	.820482
7560	6	.827115	071	363	.827406
7620	7	.833980	070	367	.834277
7680	8	.840792	070	371	.841093
7740	9	.847551	069	375	.847857
7800	10	.854257	068	379	.854568
7860	11	6.860912	067	383	6.861228
7920	12	.867517	066	387	.867837
7980	13	.874071	066	391	.874396
8040	14	.880577	065	395	.880907
8100	15	.887034	064	399	.887369
8160	16	.893443	063	403	.893783
8220	17	.899806	062	407	.900151
8280	18	.906122	061	411	.906472
8340	19	.912393	061	416	.912748
8400	20	.918618	060	420	.918979
8460	21	6.924800	059	424	6.925165
8520	22	.930937	058	429	.931308
8580	23	.937032	057	433	.937408
8640	24	.943084	056	437	.943465
8700	25	.949094	055	442	.949480
8760	26	.955063	054	446	.955455
8820	27	.960991	054	451	.961388
8880	28	.966879	053	455	.967281
8940	29	.972727	052	460	.973135
9000	30	.978536	051	464	.978949
9060	31	6.984306	050	469	6.984725
9120	32	.990039	049	474	.990463
9180	33	6.995733	048	478	6.996164
9240	34	7.001391	047	483	7.001827
9300	35	.007012	046	488	.007454
9360	36	.012597	045	493	.013044
9420	37	.018146	044	497	.018599
9480	38	.023660	043	502	.024119
9540	39	.029139	042	507	.029604
9600	40	.034584	041	512	.035054
9660	41	7.039995	040	517	7.040471
9720	42	.045372	039	522	.045854
9780	43	.050716	038	527	.051204
9840	44	.056028	037	532	.056522
9900	45	.061307	036	537	.061807
9960	46	.066554	035	542	.067061
10020	47	.071770	034	547	.072282
10080	48	.076954	033	552	.077473
10140	49	.082108	032	557	.082633
10200	50	.087232	031	562	.087763
10260	51	7.092325	030	568	7.092862
10320	52	.097389	029	573	.097932
10380	53	.102423	028	578	.102973
10440	54	.107428	027	584	.107985
10500	55	.112405	026	589	.112968
10560	56	.117353	025	594	.117922
10620	57	.122273	024	600	.122849
10680	58	.127165	023	605	.127748
10740	59	.132030	022	611	.132619
10800	60	7.136868	021	616	7.137464

3°

"	'	Vers.	q - 2l		Ex. sec.
			9.070*		
10800	0	7.136868	021	616	7.137464
10860	1	.141679	019	622	.142281
10920	2	.146464	018	627	.147072
10980	3	.151222	017	633	.151837
11040	4	.155954	016	638	.156577
11100	5	.160661	015	644	.161290
11160	6	.165342	014	650	.165978
11220	7	.169998	013	655	.170641
11280	8	.174630	011	661	.175279
11340	9	.179236	010	667	.179893
11400	10	.183819	009	673	.184483
11460	11	7.188377	008	679	7.189048
11520	12	.192912	007	685	.193589
11580	13	.197423	006	690	.198108
11640	14	.201910	004	696	.202602
11700	15	.206375	003	702	.207074
11760	16	.210817	002	708	.211523
11820	17	.215236	001	714	.215949
11880	18	.219633	*00	720	.220353
11940	19	.224007	998	727	.224735
12000	20	.228360	997	733	.229095
12060	21	7.232691	996	739	7.233433
12120	22	.237000	995	745	.237750
12180	23	.241288	994	751	.242046
12240	24	.245555	992	757	.246320
12300	25	.249801	991	764	.250574
12360	26	.254027	990	770	.254807
12420	27	.258232	989	776	.259019
12480	28	.262416	987	783	.263212
12540	29	.266581	986	789	.267384
12600	30	.270726	985	795	.271537
12660	31	7.274851	983	802	7.275669
12720	32	.278956	982	808	.279783
12780	33	.283043	981	815	.283877
12840	34	.287110	980	821	.287952
12900	35	.291158	978	828	.292007
12960	36	.295187	977	835	.296045
13020	37	.299197	976	841	.300063
13080	38	.303190	974	848	.304063
13140	39	.307164	973	855	.308045
13200	40	.311119	972	861	.312009
13260	41	7.315057	970	868	7.315955
13320	42	.318977	969	875	.319883
13380	43	.322880	967	882	.323794
13440	44	.326765	966	889	.327687
13500	45	.330632	965	896	.331563
13560	46	.334483	963	902	.335422
13620	47	.338316	962	908	.339264
13680	48	.342133	961	916	.343089
13740	49	.345933	959	923	.346897
13800	50	.349716	958	930	.350689
13860	51	7.353483	956	938	7.354464
13920	52	.357233	955	945	.358223
13980	53	.360968	953	952	.361966
14040	54	.364686	952	959	.365693
14100	55	.368389	951	966	.369404
14160	56	.372076	949	973	.373100
14220	57	.375747	948	981	.376780
14280	58	.379403	946	988	.380444
14340	59	.383043	945	995	.384094
14400	60	7.386668	943	*03	7.387728

9.069* 9.071*

4°					5°				
'	Vers.	D. 1".	Ex. sec.	D. 1".	'	Vers.	D. 1".	Ex. sec.	D. 1".
0	7.386668	60.17	7.387728	60.32	0	7.580389	48.15	7.582045	48.33
1	.390278	59.93	.391347	60.07	1	.583278	47.98	.584945	48.17
2	.393874	59.67	.394951	59.82	2	.586157	47.82	.587835	48.00
3	.397454	59.43	.398540	59.57	3	.589026	47.67	.590715	47.87
4	.401020	59.18	.402114	59.33	4	.591886	47.52	.593587	47.70
5	.404571	58.93	.405674	59.10	5	.594737	47.35	.596449	47.53
6	.408107	58.70	.409220	58.85	6	.597578	47.20	.599301	47.38
7	.411629	58.47	.412751	58.62	7	.600410	47.05	.602144	47.25
8	.415137	58.23	.416268	58.38	8	.603233	46.90	.604979	47.08
9	.418631	58.00	.419771	58.15	9	.606047	46.73	.607904	46.92
10	.422111	57.77	.423260	57.92	10	.608851	46.60	.610619	46.78
11	7.425577	57.53	7.426735	57.70	11	7.611647	46.43	7.613426	46.63
12	.429029	57.30	.430197	57.45	12	.614433	46.30	.616224	46.48
13	.432467	57.08	.433644	57.25	13	.617211	46.15	.619013	46.35
14	.435892	56.85	.437079	57.00	14	.619980	45.98	.621794	46.18
15	.439303	56.63	.440499	56.80	15	.622739	45.87	.624565	46.05
16	.442701	56.42	.443907	56.57	16	.625491	45.70	.627328	45.90
17	.446086	56.20	.447301	56.35	17	.628233	45.57	.630082	45.75
18	.449458	55.97	.450682	56.13	18	.630967	45.42	.632827	45.62
19	.452816	55.77	.454050	55.92	19	.633692	45.28	.635564	45.48
20	.456162	55.55	.457405	55.72	20	.636409	45.13	.638293	45.33
21	7.459495	55.33	7.460748	55.48	21	7.639117	44.98	7.641013	45.18
22	.462815	55.12	.464077	55.28	22	.641816	44.87	.643724	45.07
23	.466122	54.92	.467394	55.08	23	.644508	44.72	.646428	44.90
24	.469417	54.70	.470699	54.87	24	.647191	44.57	.649122	44.78
25	.472699	54.50	.473991	54.65	25	.649865	44.45	.651809	44.65
26	.475969	54.28	.477270	54.47	26	.652532	44.30	.654488	44.50
27	.479226	54.10	.480538	54.25	27	.655190	44.17	.657158	44.37
28	.482472	53.88	.483793	54.05	28	.657840	44.05	.659820	44.23
29	.485705	53.70	.487036	53.85	29	.660483	43.90	.662474	44.12
30	.488927	53.48	.490267	53.67	30	.663117	43.77	.665121	43.97
31	7.492136	53.28	7.493487	53.45	31	7.665743	43.63	7.667759	43.83
32	.495333	53.10	.496694	53.27	32	.668361	43.50	.670389	43.72
33	.498519	52.90	.499890	53.07	33	.670971	43.38	.673012	43.57
34	.501693	52.72	.503074	52.88	34	.673574	43.23	.675626	43.45
35	.504856	52.52	.506247	52.68	35	.676168	43.12	.678233	43.33
36	.508007	52.33	.509408	52.50	36	.678755	42.98	.680833	43.18
37	.511147	52.13	.512558	52.32	37	.681334	42.87	.683424	43.07
38	.514275	51.95	.515697	52.12	38	.683906	42.73	.686008	42.95
39	.517392	51.77	.518824	51.93	39	.686470	42.60	.688585	42.82
40	.520498	51.58	.521940	51.77	40	.689026	42.48	.691154	42.68
41	7.523598	51.40	7.525046	51.57	41	7.691575	42.35	7.693715	42.57
42	.526677	51.22	.528140	51.38	42	.694116	42.23	.696269	42.43
43	.529750	51.03	.531223	51.22	43	.696650	42.12	.698815	42.33
44	.532812	50.85	.534296	51.02	44	.699177	41.98	.701355	42.20
45	.535863	50.68	.537357	50.85	45	.701696	41.87	.703887	42.07
46	.538904	50.50	.540408	50.68	46	.704208	41.73	.706411	41.97
47	.541934	50.32	.543449	50.50	47	.706712	41.63	.708929	41.83
48	.544953	50.15	.546479	50.33	48	.709210	41.50	.711439	41.72
49	.547962	49.98	.549499	50.15	49	.711700	41.38	.713942	41.60
50	.550961	49.80	.552508	49.98	50	.714183	41.27	.716438	41.48
51	7.553949	49.63	7.555507	49.80	51	7.716659	41.15	7.718927	41.37
52	.556927	49.47	.558495	49.65	52	.719128	41.03	.721409	41.25
53	.559895	49.28	.561474	49.47	53	.721590	40.92	.723884	41.13
54	.562852	49.13	.564442	49.32	54	.724045	40.80	.726352	41.02
55	.565800	48.95	.567401	49.13	55	.726493	40.68	.728813	40.90
56	.568737	48.80	.570349	48.98	56	.728934	40.57	.731267	40.78
57	.571665	48.63	.573288	48.82	57	.731368	40.47	.733714	40.68
58	.574583	48.47	.576217	48.65	58	.733796	40.33	.736155	40.57
59	.577491	48.30	.579136	48.48	59	.736216	40.23	.738589	40.45
60	7.580389	48.15	7.582045	48.33	60	7.738630	40.13	7.741016	40.38

6°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	7.738630	40.13	7.741016	40.33
1	.741038	40.00	.743436	40.23
2	.743438	39.90	.745850	40.13
3	.745832	39.78	.748258	40.00
4	.748219	39.68	.750658	39.90
5	.750600	39.57	.753052	39.80
6	.752974	39.47	.755440	39.68
7	.755342	39.35	.757821	39.58
8	.757703	39.25	.760196	39.48
9	.760058	39.13	.762565	39.37
10	.762406	39.05	.764927	39.25
11	7.764749	38.92	7.767282	39.17
12	.767084	38.83	.769632	39.05
13	.769414	38.72	.771975	38.95
14	.771737	38.62	.774312	38.85
15	.774054	38.52	.776643	38.75
16	.776365	38.42	.778968	38.63
17	.778670	38.30	.781286	38.55
18	.780968	38.22	.783599	38.43
19	.783261	38.10	.785905	38.35
20	.785547	38.02	.788206	38.23
21	7.787828	37.90	7.790500	38.15
22	.790102	37.82	.792789	38.08
23	.792371	37.70	.795071	37.95
24	.794633	37.62	.797348	37.85
25	.796890	37.52	.799619	37.75
26	.799141	37.40	.801884	37.65
27	.801385	37.33	.804143	37.57
28	.803625	37.22	.806397	37.45
29	.805858	37.13	.808644	37.37
30	.808086	37.03	.810886	37.28
31	7.810308	36.93	7.813123	37.17
32	.812524	36.83	.815353	37.08
33	.814734	36.75	.817578	37.00
34	.816939	36.67	.819798	36.90
35	.819139	36.55	.822012	36.80
36	.821332	36.48	.824220	36.72
37	.823521	36.37	.826423	36.62
38	.825703	36.28	.828620	36.53
39	.827880	36.20	.830812	36.45
40	.830052	36.10	.832999	36.35
41	7.832218	36.02	7.835180	36.27
42	.834379	35.93	.837356	36.17
43	.836535	35.83	.839526	36.08
44	.838685	35.75	.841691	36.00
45	.840830	35.65	.843851	35.90
46	.842969	35.58	.845005	35.83
47	.845104	35.48	.848155	35.73
48	.847233	35.40	.850299	35.63
49	.849357	35.30	.852437	35.57
50	.851475	35.23	.854571	35.48
51	7.853589	35.13	7.856700	35.38
52	.855697	35.05	.858823	35.32
53	.857800	34.97	.860942	35.22
54	.859898	34.88	.863055	35.13
55	.861991	34.80	.865163	35.05
56	.864079	34.72	.867266	34.98
57	.866162	34.63	.869365	34.88
58	.868240	34.55	.871458	34.80
59	.870313	34.47	.873546	34.73
60	7.872381	34.38	7.875630	34.63

7°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	7.872381	34.38	7.875630	34.63
1	.874444	34.30	.877708	34.57
2	.876502	34.22	.879782	34.48
3	.878555	34.13	.881851	34.40
4	.880003	34.07	.883915	34.32
5	.882647	33.98	.885974	34.25
6	.884686	33.90	.888029	34.15
7	.886720	33.82	.890078	34.08
8	.888749	33.73	.892123	34.02
9	.890773	33.67	.894164	33.92
10	.892793	33.58	.896199	33.85
11	7.894808	33.50	7.898230	33.77
12	.896818	33.43	.900256	33.70
13	.898824	33.35	.902278	33.62
14	.900825	33.27	.904295	33.53
15	.902821	33.20	.906307	33.47
16	.904813	33.12	.908315	33.40
17	.906800	33.05	.910319	33.30
18	.908783	32.97	.912317	33.25
19	.910761	32.90	.914312	33.17
20	.912735	32.82	.916302	33.08
21	7.914704	32.73	7.918287	33.02
22	.916668	32.68	.920268	32.95
23	.918629	32.58	.922245	32.87
24	.920584	32.53	.924217	32.78
25	.922536	32.45	.926184	32.73
26	.924483	32.37	.928148	32.65
27	.926425	32.32	.930107	32.58
28	.928364	32.22	.932062	32.50
29	.930297	32.17	.934012	32.43
30	.932227	32.08	.935958	32.37
31	7.934152	32.02	7.937900	32.30
32	.936073	31.95	.938938	32.23
33	.937990	31.88	.941772	32.15
34	.939903	31.80	.943701	32.08
35	.941811	31.73	.945626	32.02
36	.943715	31.67	.947547	31.95
37	.945615	31.60	.949464	31.87
38	.947511	31.52	.951376	31.82
39	.949402	31.47	.953285	31.73
40	.951290	31.38	.955189	31.68
41	7.953173	31.32	7.957090	31.60
42	.955052	31.27	.958986	31.53
43	.956928	31.18	.960878	31.48
44	.958799	31.12	.962767	31.40
45	.960666	31.05	.964651	31.33
46	.962529	30.98	.966531	31.28
47	.964388	30.92	.968408	31.20
48	.966243	30.85	.970280	31.13
49	.968094	30.78	.972148	31.08
50	.969941	30.73	.974013	31.02
51	7.971785	30.65	7.975874	30.93
52	.973624	30.58	.977730	30.88
53	.975459	30.53	.979583	30.82
54	.977291	30.45	.981432	30.75
55	.979118	30.40	.983277	30.70
56	.980942	30.33	.985119	30.62
57	.982762	30.27	.986956	30.57
58	.984578	30.22	.988790	30.50
59	.986391	30.13	.990620	30.43
60	7.988199	30.08	7.992446	30.38

8°

'	Vers.	D. 1°.	Ex. sec.	D. 1°.
0	7.988199	30.08	7.992446	30.38
1	.990004	30.02	.994269	30.32
2	.991805	29.95	.996088	30.25
3	.993602	29.88	.997903	30.18
4	.995395	29.83	7.999714	30.13
5	.997185	29.77	8.001522	30.07
6	7.998971	29.72	.003326	30.00
7	8.000754	29.63	.005126	29.95
8	.002532	29.60	.006923	29.88
9	.004308	29.52	.008716	29.83
10	.006079	29.47	.010506	29.77
11	8.007847	29.40	8.012292	29.70
12	.009611	29.35	.014074	29.65
13	.011372	29.28	.015853	29.58
14	.013129	29.22	.017628	29.53
15	.014882	29.17	.019400	29.47
16	.016632	29.10	.021168	29.42
17	.018378	29.05	.022933	29.35
18	.020121	29.00	.024694	29.30
19	.021861	28.93	.026452	29.23
20	.023597	28.87	.028206	29.18
21	8.025329	28.82	8.029957	29.13
22	.027058	28.75	.031705	29.07
23	.028783	28.70	.033449	29.00
24	.030505	28.65	.035189	28.97
25	.032224	28.58	.036927	28.90
26	.033939	28.53	.038661	28.83
27	.035651	28.47	.040391	28.78
28	.037359	28.42	.042118	28.73
29	.039064	28.37	.043842	28.68
30	.040766	28.30	.045563	28.62
31	8.042464	28.25	8.047280	28.57
32	.044159	28.20	.048994	28.50
33	.045851	28.13	.050704	28.47
34	.047539	28.08	.052412	28.40
35	.049224	28.03	.054116	28.35
36	.050906	27.98	.055817	28.28
37	.052585	27.92	.057514	28.25
38	.054260	27.87	.059209	28.18
39	.055932	27.82	.060900	28.13
40	.057601	27.75	.062588	28.08
41	8.059266	27.72	8.064273	28.03
42	.060929	27.65	.065955	27.97
43	.062588	27.60	.067633	27.93
44	.064244	27.55	.069309	27.87
45	.065897	27.48	.070981	27.82
46	.067546	27.45	.072650	27.77
47	.069193	27.38	.074316	27.72
48	.070836	27.33	.075979	27.67
49	.072476	27.30	.077639	27.60
50	.074114	27.23	.079295	27.57
51	8.075748	27.18	8.080949	27.52
52	.077379	27.13	.082600	27.45
53	.079007	27.07	.084247	27.42
54	.080631	27.03	.085892	27.37
55	.082253	26.98	.087534	27.30
56	.083872	26.93	.089172	27.27
57	.085488	26.87	.090808	27.20
58	.087100	26.83	.092440	27.17
59	.088710	26.78	.094070	27.12
60	8.090317	26.72	8.095697	27.05

9°

'	Vers.	D. 1°.	Ex. sec.	D. 1°.
0	8.090317	26.72	8.095697	27.05
1	.091920	26.68	.097320	27.02
2	.093521	26.63	.098941	26.97
3	.095119	26.58	.100559	26.92
4	.096714	26.52	.102174	26.87
5	.098305	26.48	.103786	26.82
6	.099894	26.43	.105395	26.77
7	.101480	26.40	.107001	26.73
8	.103064	26.33	.108605	26.67
9	.104644	26.28	.110205	26.63
10	.106221	26.25	.111803	26.58
11	8.107796	26.18	8.113398	26.53
12	.109367	26.15	.114990	26.48
13	.110936	26.10	.116579	26.45
14	.112502	26.05	.118166	26.38
15	.114065	26.00	.119749	26.35
16	.115625	25.95	.121330	26.30
17	.117182	25.92	.122908	26.25
18	.118737	25.87	.124483	26.22
19	.120289	25.82	.126056	26.17
20	.121838	25.77	.127626	26.12
21	8.123384	25.72	8.129193	26.07
22	.124927	25.68	.130757	26.02
23	.126468	25.63	.132318	25.98
24	.128006	25.58	.133877	25.93
25	.129541	25.55	.135433	25.90
26	.131074	25.50	.136987	25.85
27	.132604	25.45	.138538	25.80
28	.134131	25.40	.140086	25.75
29	.135655	25.37	.141631	25.72
30	.137177	25.32	.143174	25.67
31	8.138696	25.27	8.144714	25.63
32	.140212	25.23	.146252	25.58
33	.141726	25.18	.147787	25.53
34	.143237	25.13	.149319	25.50
35	.144745	25.10	.150849	25.45
36	.146251	25.05	.152376	25.40
37	.147754	25.02	.153900	25.37
38	.149255	24.95	.155422	25.33
39	.150752	24.93	.156942	25.27
40	.152248	24.88	.158458	25.25
41	8.153741	24.83	8.159973	25.18
42	.155231	24.78	.161484	25.17
43	.156718	24.75	.162994	25.10
44	.158203	24.72	.164500	25.07
45	.159686	24.67	.166004	25.03
46	.161166	24.62	.167506	24.98
47	.162643	24.58	.169005	24.95
48	.164118	24.53	.170502	24.90
49	.165590	24.50	.171996	24.87
50	.167060	24.45	.173488	24.82
51	8.168527	24.42	8.174977	24.78
52	.169992	24.37	.176464	24.73
53	.171454	24.33	.177948	24.70
54	.172914	24.30	.179430	24.65
55	.174372	24.25	.180909	24.62
56	.175827	24.20	.182386	24.58
57	.177279	24.17	.183861	24.53
58	.178729	24.13	.185333	24.50
59	.180177	24.08	.186803	24.47
60	8.181622	24.05	8.188271	24.42

10°					11°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	8.181622	24.05	8.188271	24.42	0	8.264176	21.85	8.272229	22.27
1	.183065	24.00	.189736	24.37	1	.265487	21.82	.273565	22.22
2	.184505	23.97	.191198	24.35	2	.266796	21.78	.274898	22.20
3	.185943	23.93	.192659	24.30	3	.268103	21.75	.276230	22.17
4	.187379	23.88	.194117	24.25	4	.269408	21.72	.277560	22.13
5	.188812	23.85	.195572	24.22	5	.270711	21.68	.278888	22.08
6	.190243	23.80	.197025	24.18	6	.272012	21.65	.280213	22.07
7	.191671	23.77	.198476	24.15	7	.273311	21.62	.281537	22.03
8	.193097	23.73	.199925	24.10	8	.274608	21.58	.282859	22.00
9	.194521	23.68	.201371	24.07	9	.275903	21.57	.284179	21.98
10	.195942	23.65	.202815	24.03	10	.277197	21.52	.285498	21.93
11	8.197361	23.62	8.204257	23.98	11	8.278488	21.48	8.286814	21.90
12	.198778	23.57	.205696	23.95	12	.279777	21.47	.288128	21.88
13	.200192	23.53	.207133	23.92	13	.281065	21.42	.289441	21.83
14	.201604	23.50	.208568	23.88	14	.282350	21.40	.290751	21.82
15	.203014	23.45	.210001	23.83	15	.283634	21.37	.292060	21.78
16	.204421	23.42	.211431	23.80	16	.284916	21.33	.293367	21.75
17	.205826	23.38	.212859	23.77	17	.286196	21.28	.294672	21.72
18	.207229	23.35	.214285	23.72	18	.287473	21.27	.295975	21.65
19	.208630	23.30	.215708	23.70	19	.288749	21.25	.297276	21.67
20	.210028	23.27	.217130	23.65	20	.290024	21.20	.298576	21.62
21	8.211424	23.23	8.218549	23.62	21	8.291296	21.17	8.299873	21.60
22	.212818	23.18	.219966	23.57	22	.292566	21.15	.301169	21.57
23	.214209	23.17	.221380	23.55	23	.293835	21.10	.302463	21.53
24	.215599	23.12	.222793	23.50	24	.295101	21.08	.303755	21.50
25	.216986	23.08	.224203	23.47	25	.296366	21.05	.305045	21.48
26	.218371	23.03	.225611	23.43	26	.297629	21.02	.306334	21.43
27	.219753	23.00	.227017	23.40	27	.298890	20.98	.307620	21.42
28	.221133	22.98	.228421	23.35	28	.300149	20.95	.308905	21.38
29	.222512	22.93	.229822	23.32	29	.301406	20.93	.310188	21.35
30	.223888	22.88	.231221	23.30	30	.302662	20.90	.311469	21.33
31	8.225261	22.87	8.232619	23.25	31	8.303916	20.85	8.312749	21.28
32	.226633	22.82	.234014	23.22	32	.305167	20.85	.314026	21.27
33	.228002	22.78	.235407	23.17	33	.306418	20.80	.315302	21.23
34	.229369	22.77	.236797	23.15	34	.307666	20.77	.316576	21.22
35	.230735	22.70	.238186	23.10	35	.308912	20.75	.317849	21.17
36	.232097	22.68	.239572	23.08	36	.310157	20.72	.319119	21.15
37	.233458	22.65	.240957	23.03	37	.311400	20.68	.320388	21.12
38	.234817	22.60	.242339	23.00	38	.312641	20.65	.321655	21.08
39	.236173	22.57	.243719	22.97	39	.313880	20.62	.322920	21.05
40	.237527	22.55	.245097	22.93	40	.315117	20.60	.324183	21.03
41	8.238880	22.50	8.246473	22.90	41	8.316353	20.57	8.325445	21.00
42	.240230	22.47	.247847	22.87	42	.317587	20.53	.326705	20.98
43	.241578	22.43	.249219	22.83	43	.318819	20.50	.327964	20.93
44	.242924	22.38	.250589	22.80	44	.320049	20.48	.329220	20.92
45	.244267	22.37	.251957	22.75	45	.321278	20.45	.330475	20.88
46	.245609	22.32	.253322	22.73	46	.322505	20.42	.331728	20.87
47	.246948	22.30	.254686	22.68	47	.323730	20.38	.332980	20.82
48	.248286	22.25	.256047	22.67	48	.324953	20.37	.334229	20.80
49	.249621	22.23	.257407	22.62	49	.326175	20.33	.335477	20.78
50	.250955	22.18	.258764	22.60	50	.327395	20.30	.336724	20.73
51	8.252286	22.15	8.260120	22.55	51	8.328613	20.27	8.337968	20.72
52	.253615	22.12	.261473	22.53	52	.329829	20.25	.339211	20.70
53	.254942	22.10	.262825	22.48	53	.331044	20.22	.340453	20.65
54	.256268	22.05	.264174	22.47	54	.332257	20.18	.341692	20.63
55	.257591	22.02	.265522	22.42	55	.333468	20.17	.342930	20.60
56	.258912	21.98	.266867	22.40	56	.334678	20.13	.344166	20.58
57	.260231	21.95	.268211	22.35	57	.335886	20.10	.345401	20.55
58	.261548	21.92	.269552	22.33	58	.337092	20.07	.346634	20.52
59	.262863	21.88	.270892	22.28	59	.338296	20.05	.347865	20.50
60	8.264176	21.85	8.272229	22.27	60	8.339499	20.02	8.349095	20.47

12°

13°

	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	8.339499	20.02	8.349095	20.47	0	8.408748	18.47	8.420024	18.95
1	.340700	20.00	.350323	20.43	1	.409856	18.43	.421161	18.93
2	.341900	19.95	.351549	20.42	2	.410962	18.42	.422297	18.90
3	.343097	19.95	.352774	20.38	3	.412067	18.40	.423431	18.88
4	.344294	19.90	.353997	20.35	4	.413171	18.38	.424564	18.87
5	.345488	19.88	.355218	20.33	5	.414274	18.35	.425696	18.83
6	.346681	19.85	.356438	20.30	6	.415375	18.32	.426826	18.82
7	.347872	19.82	.357656	20.28	7	.416474	18.30	.427955	18.80
8	.349061	19.80	.358873	20.25	8	.417572	18.28	.429083	18.77
9	.350249	19.77	.360088	20.22	9	.418669	18.25	.430209	18.75
10	.351435	19.75	.361301	20.20	10	.419764	18.23	.431334	18.73
11	8.352620	19.72	8.362513	20.18	11	8.420858	18.22	8.432458	18.70
12	.353803	19.68	.363724	20.13	12	.421951	18.18	.433580	18.67
13	.354984	19.67	.364932	20.12	13	.423042	18.17	.434700	18.67
14	.356164	19.63	.366139	20.10	14	.424132	18.13	.435820	18.63
15	.357342	19.60	.367345	20.07	15	.425220	18.12	.436938	18.62
16	.358518	19.58	.368549	20.03	16	.426307	18.10	.438055	18.58
17	.359693	19.55	.369751	20.02	17	.427393	18.07	.439170	18.57
18	.360866	19.53	.370952	19.98	18	.428477	18.05	.440284	18.55
19	.362038	19.50	.372151	19.95	19	.429560	18.02	.441397	18.53
20	.363208	19.48	.373348	19.95	20	.430641	18.02	.442509	18.50
21	8.364377	19.43	8.374545	19.90	21	8.431722	17.97	8.443619	18.47
22	.365543	19.43	.375739	19.88	22	.432800	17.97	.444727	18.47
23	.366709	19.38	.376932	19.85	23	.433878	17.93	.445835	18.43
24	.367872	19.37	.378123	19.83	24	.434954	17.92	.446941	18.42
25	.369034	19.35	.379313	19.82	25	.436029	17.88	.448046	18.38
26	.370195	19.32	.380502	19.78	26	.437102	17.87	.449149	18.38
27	.371354	19.28	.381689	19.75	27	.438174	17.85	.450252	18.35
28	.372511	19.27	.382874	19.73	28	.439245	17.82	.451353	18.32
29	.373667	19.25	.384058	19.70	29	.440314	17.80	.452452	18.32
30	.374822	19.20	.385240	19.68	30	.441382	17.78	.453551	18.28
31	8.375974	19.18	8.386421	19.65	31	8.442449	17.75	8.454648	18.25
32	.377125	19.17	.387600	19.63	32	.443514	17.73	.455743	18.25
33	.378275	19.13	.388778	19.60	33	.444578	17.72	.456838	18.22
34	.379423	19.12	.389954	19.58	34	.445641	17.68	.457931	18.20
35	.380570	19.08	.391129	19.55	35	.446702	17.68	.459023	18.18
36	.381715	19.05	.392302	19.53	36	.447763	17.63	.460114	18.15
37	.382858	19.03	.393474	19.50	37	.448821	17.63	.461203	18.13
38	.384000	19.02	.394644	19.48	38	.449879	17.60	.462291	18.12
39	.385141	18.98	.395813	19.45	39	.450935	17.58	.463378	18.10
40	.386280	18.95	.396980	19.43	40	.451990	17.55	.464464	18.07
41	8.387417	18.93	8.398146	19.42	41	8.453043	17.55	8.465548	18.05
42	.388553	18.92	.399311	19.38	42	.454096	17.52	.466631	18.03
43	.389688	18.88	.400474	19.35	43	.455147	17.48	.467713	18.00
44	.390821	18.85	.401635	19.33	44	.456196	17.48	.468793	18.00
45	.391952	18.83	.402795	19.32	45	.457245	17.45	.469873	17.97
46	.393082	18.82	.403954	19.28	46	.458292	17.43	.470951	17.95
47	.394211	18.78	.405111	19.27	47	.459338	17.40	.472028	17.92
48	.395338	18.75	.406267	19.23	48	.460382	17.40	.473103	17.90
49	.396463	18.73	.407421	19.22	49	.461426	17.37	.474177	17.90
50	.397587	18.72	.408574	19.18	50	.462468	17.35	.475251	17.85
51	8.398710	18.68	8.409725	19.17	51	8.463509	17.32	8.476322	17.85
52	.399831	18.67	.410875	19.13	52	.464548	17.30	.477393	17.83
53	.400951	18.63	.412023	19.13	53	.465586	17.28	.478463	17.80
54	.402069	18.62	.413171	19.08	54	.466623	17.27	.479531	17.78
55	.403186	18.58	.414316	19.08	55	.467659	17.23	.480598	17.77
56	.404301	18.57	.415461	19.03	56	.468693	17.23	.481664	17.73
57	.405415	18.53	.416603	19.03	57	.469727	17.20	.482728	17.73
58	.406527	18.52	.417745	19.00	58	.470759	17.17	.483792	17.70
59	.407638	18.50	.418885	18.98	59	.471789	17.17	.484854	17.68
60	8.408748	18.47	8.420024	18.95	60	8.472819	17.13	8.485915	17.67

14°					15°				
'	Vers.	D. 1'.	Ex. sec.	D. 1'.	'	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	8.472819	17.13	8.485915	17.67	0	8.532425	15.98	8.547482	16.53
1	.473847	17.12	.486975	17.63	1	.533384	15.97	.548474	16.53
2	.474874	17.10	.488033	17.63	2	.534342	15.95	.549466	16.53
3	.475900	17.08	.489091	17.60	3	.535299	15.93	.550457	16.50
4	.476925	17.05	.490147	17.58	4	.536255	15.92	.551447	16.48
5	.477948	17.03	.491202	17.57	5	.537210	15.88	.552436	16.47
6	.478970	17.02	.492256	17.53	6	.538163	15.88	.553424	16.43
7	.479991	17.00	.493308	17.53	7	.539116	15.87	.554410	16.43
8	.481011	16.97	.494360	17.50	8	.540068	15.83	.555396	16.42
9	.482029	16.95	.495410	17.48	9	.541018	15.83	.556381	16.38
10	.483046	16.93	.496459	17.47	10	.541968	15.80	.557364	16.38
11	8.484062	16.92	8.497507	17.45	11	8.542916	15.78	8.558347	16.37
12	.485077	16.90	.498554	17.43	12	.543863	15.78	.559329	16.33
13	.486091	16.87	.499600	17.40	13	.544810	15.75	.560309	16.33
14	.487103	16.87	.500644	17.38	14	.545755	15.73	.561289	16.30
15	.488115	16.83	.501687	17.38	15	.546699	15.72	.562267	16.30
16	.489125	16.82	.502730	17.35	16	.547642	15.70	.563245	16.28
17	.490134	16.78	.503771	17.32	17	.548584	15.68	.564222	16.25
18	.491141	16.78	.504810	17.32	18	.549525	15.67	.565197	16.25
19	.492148	16.75	.505849	17.30	19	.550465	15.65	.566172	16.22
20	.493153	16.73	.506887	17.27	20	.551404	15.63	.567145	16.22
21	8.494157	16.72	8.507923	17.25	21	8.552342	15.62	8.568118	16.20
22	.495160	16.70	.508958	17.25	22	.553279	15.60	.569090	16.17
23	.496162	16.67	.509993	17.22	23	.554215	15.58	.570060	16.17
24	.497162	16.67	.511026	17.18	24	.555150	15.57	.571030	16.15
25	.498162	16.63	.512057	17.18	25	.556084	15.55	.571999	16.12
26	.499160	16.62	.513088	17.17	26	.557017	15.53	.572966	16.12
27	.500157	16.60	.514118	17.13	27	.557949	15.50	.573933	16.10
28	.501153	16.58	.515146	17.13	28	.558879	15.50	.574899	16.08
29	.502148	16.57	.516174	17.10	29	.559809	15.48	.575864	16.05
30	.503142	16.53	.517200	17.08	30	.560738	15.47	.576827	16.05
31	8.504134	16.52	8.518225	17.07	31	8.561666	15.43	8.577790	16.03
32	.505125	16.52	.519249	17.05	32	.562592	15.43	.578752	16.02
33	.506116	16.48	.520272	17.03	33	.563518	15.42	.579713	16.00
34	.507105	16.45	.521294	17.02	34	.564443	15.40	.580673	15.98
35	.508092	16.45	.522315	16.98	35	.565367	15.37	.581632	15.97
36	.509079	16.43	.523334	16.98	36	.566289	15.37	.582590	15.95
37	.510065	16.40	.524353	16.95	37	.567211	15.35	.583547	15.93
38	.511049	16.40	.525370	16.95	38	.568132	15.33	.584503	15.92
39	.512033	16.37	.526387	16.92	39	.569052	15.30	.585458	15.90
40	.513015	16.35	.527402	16.90	40	.569970	15.30	.586412	15.88
41	8.513996	16.33	8.528416	16.88	41	8.570888	15.28	8.587365	15.88
42	.514976	16.32	.529429	16.87	42	.571805	15.27	.588318	15.85
43	.515955	16.28	.530441	16.85	43	.572721	15.25	.589269	15.83
44	.516932	16.28	.531452	16.83	44	.573636	15.22	.590219	15.83
45	.517909	16.25	.532462	16.82	45	.574549	15.22	.591169	15.80
46	.518884	16.25	.533471	16.78	46	.575462	15.20	.592117	15.80
47	.519859	16.22	.534478	16.78	47	.576374	15.18	.593065	15.78
48	.520832	16.20	.535485	16.75	48	.577285	15.17	.594012	15.75
49	.521804	16.18	.536490	16.75	49	.578195	15.15	.594957	15.75
50	.522775	16.17	.537495	16.72	50	.579104	15.13	.595902	15.73
51	8.523745	16.15	8.538498	16.72	51	8.580012	15.12	8.596846	15.72
52	.524714	16.13	.539501	16.68	52	.580919	15.10	.597789	15.70
53	.525682	16.10	.540502	16.67	53	.581825	15.08	.598731	15.68
54	.526648	16.10	.541502	16.65	54	.582730	15.07	.599672	15.67
55	.527614	16.07	.542501	16.63	55	.583634	15.05	.600612	15.65
56	.528578	16.07	.543499	16.63	56	.584537	15.05	.601551	15.65
57	.529542	16.03	.544497	16.60	57	.585440	15.02	.602490	15.62
58	.530504	16.02	.545493	16.58	58	.586341	15.00	.603427	15.60
59	.531465	16.00	.546488	16.57	59	.587241	15.00	.604363	15.60
60	8.532425	15.98	8.547482	16.53	60	8.588141	14.97	8.605299	15.58

16°					17°				
'	Vers.	D. 1'.	Ex. sec.	D. 1'.	'	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	8.588141	14.97	8.605299	15.58	0	8.640434	14.08	8.659838	14.72
1	.589039	14.95	.606234	15.55	1	.641279	14.07	.660721	14.72
2	.589936	14.95	.607167	15.55	2	.642123	14.05	.661604	14.70
3	.590833	14.93	.608100	15.53	3	.642966	14.05	.662486	14.68
4	.591729	14.90	.609032	15.52	4	.643809	14.02	.663367	14.68
5	.592623	14.90	.609963	15.50	5	.644650	14.02	.664248	14.65
6	.593517	14.88	.610893	15.50	6	.645491	14.00	.665127	14.65
7	.594410	14.87	.611823	15.47	7	.646331	13.98	.666006	14.63
8	.595302	14.83	.612751	15.45	8	.647170	13.97	.666884	14.62
9	.596192	14.83	.613678	15.45	9	.648008	13.95	.667761	14.60
10	.597082	14.82	.614605	15.43	10	.648845	13.95	.668637	14.60
11	8.597971	14.82	8.615531	15.42	11	8.649682	13.93	8.669513	14.58
12	.598860	14.78	.616456	15.38	12	.650518	13.92	.670388	14.57
13	.599747	14.77	.617379	15.38	13	.651353	13.90	.671262	14.55
14	.600633	14.75	.618302	15.38	14	.652187	13.88	.672135	14.55
15	.601518	14.75	.619225	15.35	15	.653020	13.87	.673008	14.52
16	.602403	14.72	.620146	15.33	16	.653852	13.87	.673879	14.52
17	.603286	14.72	.621066	15.33	17	.654684	13.85	.674750	14.50
18	.604169	14.70	.621986	15.30	18	.655515	13.83	.675620	14.50
19	.605051	14.67	.622904	15.30	19	.656345	13.82	.676490	14.47
20	.605931	14.67	.623822	15.28	20	.657174	13.82	.677358	14.47
21	8.606811	14.65	8.624739	15.27	21	8.658003	13.78	8.678226	14.45
22	.607690	14.63	.625655	15.25	22	.658830	13.78	.679093	14.45
23	.608568	14.62	.626570	15.23	23	.659657	13.77	.679960	14.42
24	.609445	14.60	.627484	15.23	24	.660483	13.75	.680825	14.42
25	.610321	14.60	.628398	15.20	25	.661308	13.73	.681690	14.40
26	.611197	14.57	.629310	15.20	26	.662132	13.73	.682554	14.38
27	.612071	14.57	.630222	15.18	27	.662956	13.72	.683417	14.38
28	.612945	14.53	.631133	15.17	28	.663779	13.70	.684280	14.35
29	.613817	14.53	.632043	15.15	29	.664601	13.68	.685141	14.35
30	.614689	14.52	.632952	15.13	30	.665422	13.67	.686002	14.35
31	8.615560	14.50	8.633360	15.13	31	8.666242	13.67	8.686863	14.32
32	.616430	14.48	.634768	15.10	32	.667062	13.65	.687722	14.32
33	.617299	14.47	.635674	15.10	33	.667881	13.63	.688581	14.30
34	.618167	14.45	.636580	15.08	34	.668699	13.62	.689439	14.28
35	.619034	14.45	.637485	15.07	35	.669516	13.60	.690296	14.28
36	.619901	14.42	.638399	15.05	36	.670332	13.60	.691153	14.25
37	.620766	14.42	.639292	15.05	37	.671148	13.58	.692008	14.25
38	.621631	14.40	.640195	15.02	38	.671963	13.57	.692863	14.25
39	.622495	14.38	.641096	15.02	39	.672777	13.55	.693718	14.22
40	.623358	14.37	.641997	15.00	40	.673590	13.55	.694571	14.22
41	8.624220	14.35	8.642397	14.98	41	8.674403	13.53	8.695424	14.20
42	.625081	14.33	.643796	14.97	42	.675215	13.52	.696276	14.18
43	.625941	14.33	.644694	14.95	43	.676026	13.50	.697127	14.18
44	.626801	14.30	.645591	14.95	44	.676836	13.48	.697978	14.17
45	.627659	14.30	.646488	14.93	45	.677645	13.48	.698828	14.15
46	.628517	14.28	.647384	14.92	46	.678454	13.47	.699677	14.13
47	.629374	14.27	.648279	14.90	47	.679262	13.45	.700525	14.13
48	.630230	14.25	.649173	14.88	48	.680069	13.43	.701373	14.12
49	.631085	14.23	.650066	14.87	49	.680875	13.43	.702220	14.10
50	.631939	14.22	.650958	14.87	50	.681681	13.42	.703066	14.10
51	8.632792	14.22	8.651850	14.85	51	8.682486	13.40	8.703912	14.07
52	.633645	14.18	.652741	14.83	52	.683290	13.38	.704756	14.07
53	.634496	14.18	.653631	14.82	53	.684093	13.38	.705600	14.07
54	.635347	14.17	.654520	14.80	54	.684896	13.35	.706444	14.03
55	.636197	14.15	.655408	14.80	55	.685697	13.35	.707288	14.03
56	.637046	14.13	.656296	14.77	56	.686498	13.35	.708128	14.02
57	.637894	14.13	.657182	14.77	57	.687299	13.32	.708969	14.02
58	.638742	14.10	.658068	14.77	58	.688098	13.32	.709810	14.00
59	.639588	14.10	.658954	14.73	59	.688897	13.30	.710650	13.98
60	8.640434	14.08	8.659838	14.72	60	8.689695	13.28	8.711489	13.97

18°					19°				
'	Vers.	D. 1'.	Ex. sec.	D. 1'.	'	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	8.689695	13.28	8.711489	13.97	0	8.736248	12.58	8.760578	13.30
1	.690492	13.28	.712327	13.95	1	.737003	12.57	.761376	13.30
2	.691289	13.25	.713164	13.95	2	.737757	12.55	.762174	13.28
3	.692084	13.25	.714001	13.95	3	.738510	12.55	.762971	13.27
4	.692879	13.25	.714838	13.92	4	.739263	12.53	.763767	13.27
5	.693674	13.22	.715673	13.92	5	.740015	12.52	.764563	13.25
6	.694467	13.22	.716508	13.90	6	.740766	12.50	.765358	13.23
7	.695260	13.20	.717342	13.88	7	.741516	12.50	.766152	13.23
8	.696052	13.18	.718175	13.88	8	.742266	12.50	.766946	13.22
9	.696843	13.18	.719008	13.87	9	.743016	12.47	.767739	13.20
10	.697634	13.17	.719840	13.85	10	.743764	12.47	.768531	13.20
11	8.698424	13.15	8.720671	13.85	11	8.744512	12.45	8.769323	13.18
12	.699213	13.13	.721502	13.83	12	.745259	12.45	.770114	13.18
13	.700001	13.13	.722332	13.82	13	.746006	12.43	.770905	13.17
14	.700789	13.12	.723161	13.80	14	.746752	12.42	.771695	13.15
15	.701576	13.10	.723989	13.80	15	.747497	12.42	.772484	13.15
16	.702362	13.08	.724817	13.78	16	.748242	12.40	.773273	13.13
17	.703147	13.08	.725644	13.78	17	.748986	12.38	.774061	13.13
18	.703932	13.07	.726471	13.77	18	.749729	12.38	.774849	13.12
19	.704716	13.05	.727297	13.75	19	.750472	12.37	.775636	13.10
20	.705499	13.05	.728122	13.73	20	.751214	12.35	.776422	13.08
21	8.706282	13.02	8.728946	13.73	21	8.751955	12.35	8.777207	13.10
22	.707063	13.02	.729770	13.72	22	.752696	12.33	.777993	13.07
23	.707844	13.02	.730593	13.70	23	.753436	12.32	.778777	13.07
24	.708625	12.98	.731415	13.70	24	.754175	12.32	.779561	13.05
25	.709404	12.98	.732237	13.68	25	.754914	12.30	.780344	13.05
26	.710183	12.97	.733058	13.67	26	.755652	12.28	.781127	13.03
27	.710961	12.97	.733878	13.67	27	.756389	12.28	.781909	13.02
28	.711739	12.95	.734698	13.65	28	.757126	12.27	.782690	13.02
29	.712516	12.93	.735517	13.63	29	.757862	12.27	.783471	13.00
30	.713292	12.92	.736335	13.63	30	.758598	12.25	.784251	13.00
31	8.714067	12.92	8.737153	13.62	31	8.759333	12.23	8.785031	12.98
32	.714842	12.90	.737970	13.60	32	.760067	12.23	.785810	12.97
33	.715616	12.88	.738786	13.60	33	.760801	12.22	.786588	12.97
34	.716389	12.87	.739602	13.58	34	.761534	12.20	.787366	12.97
35	.717161	12.87	.740417	13.57	35	.762266	12.20	.788144	12.93
36	.717933	12.85	.741231	13.57	36	.762998	12.18	.788920	12.93
37	.718704	12.85	.742045	13.55	37	.763729	12.17	.789696	12.93
38	.719475	12.82	.742858	13.53	38	.764459	12.17	.790472	12.92
39	.720244	12.82	.743670	13.53	39	.765189	12.15	.791247	12.90
40	.721013	12.82	.744482	13.52	40	.765918	12.15	.792021	12.90
41	8.721782	12.78	8.745293	13.50	41	8.766647	12.12	8.792795	12.88
42	.722549	12.78	.746103	13.50	42	.767374	12.12	.793568	12.87
43	.723316	12.78	.746913	13.48	43	.768102	12.10	.794340	12.87
44	.724083	12.75	.747722	13.47	44	.768828	12.10	.795112	12.87
45	.724848	12.75	.748530	13.47	45	.769554	12.10	.795884	12.83
46	.725613	12.73	.749338	13.45	46	.770280	12.08	.796654	12.85
47	.726377	12.72	.750145	13.43	47	.771005	12.07	.797425	12.82
48	.727140	12.72	.750951	13.43	48	.771729	12.05	.798194	12.82
49	.727903	12.70	.751757	13.42	49	.772452	12.05	.798963	12.82
50	.728665	12.70	.752562	13.42	50	.773175	12.05	.799732	12.80
51	8.729427	12.67	8.753367	13.40	51	8.773898	12.02	8.800500	12.78
52	.730187	12.67	.754171	13.38	52	.774619	12.02	.801267	12.78
53	.730947	12.67	.754974	13.37	53	.775340	12.02	.802034	12.77
54	.731707	12.63	.755776	13.37	54	.776061	12.00	.802800	12.75
55	.732465	12.63	.756578	13.37	55	.776781	11.98	.803565	12.75
56	.733223	12.63	.757380	13.33	56	.777500	11.97	.804330	12.75
57	.733981	12.60	.758180	13.33	57	.778218	11.97	.805095	12.73
58	.734737	12.60	.758980	13.33	58	.778936	11.97	.805859	12.72
59	.735493	12.58	.759780	13.30	59	.779654	11.93	.806622	12.72
60	8.736248	12.58	8.760578	13.30	60	8.780370	11.95	8.807385	12.70

20°					21°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	8.780379	11.95	8.807385	12.70	0	8.822296	11.35	8.852144	12.17
1	.781087	11.92	.808147	12.68	1	.822977	11.35	.852874	12.17
2	.781802	11.92	.808908	12.68	2	.823658	11.33	.853604	12.13
3	.782517	11.90	.809669	12.68	3	.824338	11.33	.854332	12.15
4	.783231	11.90	.810430	12.67	4	.825018	11.32	.855061	12.13
5	.783945	11.88	.811190	12.65	5	.825697	11.32	.855789	12.12
6	.784658	11.88	.811949	12.65	6	.826376	11.30	.856516	12.12
7	.785371	11.87	.812708	12.63	7	.827054	11.28	.857243	12.10
8	.786083	11.85	.813466	12.63	8	.827731	11.28	.857969	12.10
9	.786794	11.85	.814224	12.62	9	.828408	11.28	.858695	12.08
10	.787505	11.83	.814981	12.60	10	.829085	11.27	.859420	12.08
11	8.788215	11.82	8.815737	12.60	11	8.829761	11.25	8.860145	12.07
12	.788924	11.82	.816493	12.60	12	.830436	11.25	.860869	12.07
13	.789633	11.82	.817249	12.58	13	.831111	11.23	.861593	12.05
14	.790342	11.78	.818004	12.57	14	.831785	11.23	.862316	12.05
15	.791049	11.78	.818758	12.57	15	.832459	11.22	.863039	12.03
16	.791756	11.78	.819512	12.55	16	.833132	11.20	.863761	12.03
17	.792463	11.77	.820265	12.55	17	.833804	11.20	.864483	12.02
18	.793169	11.75	.821018	12.53	18	.834476	11.20	.865204	12.02
19	.793874	11.75	.821770	12.52	19	.835148	11.18	.865925	12.02
20	.794579	11.73	.822521	12.52	20	.835819	11.17	.866646	11.98
21	8.795283	11.73	8.823272	12.52	21	8.836489	11.17	8.867365	12.00
22	.795987	11.72	.824023	12.50	22	.837159	11.17	.868085	11.98
23	.796690	11.70	.824773	12.48	23	.837829	11.15	.868804	11.97
24	.797392	11.70	.825522	12.48	24	.838498	11.13	.869522	11.97
25	.798094	11.68	.826271	12.47	25	.839166	11.13	.870240	11.95
26	.798795	11.68	.827019	12.47	26	.839834	11.12	.870957	11.95
27	.799496	11.67	.827767	12.45	27	.840501	11.12	.871674	11.93
28	.800196	11.67	.828514	12.45	28	.841168	11.10	.872390	11.93
29	.800896	11.63	.829261	12.43	29	.841834	11.10	.873106	11.93
30	.801594	11.65	.830007	12.42	30	.842500	11.08	.873822	11.92
31	8.802293	11.63	8.830752	12.42	31	8.843165	11.07	8.874537	11.90
32	.802991	11.62	.831497	12.42	32	.843829	11.07	.875251	11.90
33	.803688	11.60	.832242	12.40	33	.844493	11.07	.875965	11.88
34	.804384	11.60	.832986	12.38	34	.845157	11.05	.876678	11.88
35	.805080	11.60	.833729	12.38	35	.845820	11.05	.877391	11.88
36	.805776	11.58	.834472	12.38	36	.846483	11.03	.878104	11.87
37	.806471	11.57	.835215	12.37	37	.847145	11.02	.878816	11.87
38	.807165	11.57	.835957	12.35	38	.847806	11.02	.879528	11.85
39	.807859	11.55	.836698	12.35	39	.848467	11.00	.880239	11.83
40	.808552	11.53	.837439	12.33	40	.849127	11.00	.880949	11.83
41	8.809244	11.53	8.838179	12.33	41	8.849787	11.00	8.881659	11.83
42	.809936	11.53	.838919	12.32	42	.850447	10.98	.882369	11.82
43	.810628	11.52	.839658	12.30	43	.851106	10.97	.883078	11.82
44	.811319	11.50	.840396	12.32	44	.851764	10.97	.883787	11.80
45	.812009	11.50	.841135	12.28	45	.852422	10.95	.884495	11.80
46	.812699	11.48	.841872	12.28	46	.853079	10.95	.885203	11.78
47	.813388	11.48	.842609	12.28	47	.853736	10.93	.885910	11.78
48	.814077	11.47	.843346	12.27	48	.854392	10.93	.886617	11.77
49	.814765	11.45	.844082	12.25	49	.855048	10.92	.887323	11.77
50	.815452	11.45	.844817	12.25	50	.855703	10.92	.888029	11.75
51	8.816139	11.43	8.845552	12.25	51	8.856358	10.90	8.888734	11.75
52	.816825	11.43	.846287	12.23	52	.857012	10.90	.889439	11.75
53	.817511	11.42	.847021	12.22	53	.857666	10.88	.890144	11.73
54	.818196	11.42	.847754	12.22	54	.858319	10.88	.890848	11.72
55	.818881	11.40	.848487	12.22	55	.858972	10.87	.891551	11.72
56	.819565	11.40	.849220	12.20	56	.859624	10.87	.892254	11.72
57	.820249	11.38	.849952	12.18	57	.860276	10.85	.892957	11.70
58	.820932	11.37	.850683	12.18	58	.860927	10.85	.893659	11.70
59	.821614	11.37	.851414	12.17	59	.861578	10.83	.894361	11.68
60	8.822296	11.35	8.852144	12.17	60	8.862228	10.82	8.895062	11.68

22°					23°				
'	Vers.	D. 1".	Ex. sec.	D. 1".	'	Vers.	D. 1".	Ex. sec.	D. 1".
0	8.862228	10.82	8.895062	11.68	0	8.900341	10.33	8.936315	11.23
1	.862877	10.83	.895763	11.67	1	.900961	10.35	.936989	11.23
2	.863527	10.80	.896463	11.67	2	.901582	10.32	.937663	11.22
3	.864175	10.80	.897163	11.65	3	.902201	10.33	.938336	11.22
4	.864823	10.80	.897862	11.65	4	.902821	10.32	.939009	11.22
5	.865471	10.78	.898561	11.63	5	.903440	10.30	.939682	11.20
6	.866118	10.78	.899259	11.63	6	.904058	10.30	.940354	11.20
7	.866765	10.77	.899957	11.63	7	.904676	10.28	.941026	11.20
8	.867411	10.77	.900655	11.62	8	.905293	10.28	.941698	11.18
9	.868057	10.75	.901352	11.60	9	.905910	10.28	.942369	11.17
10	.868702	10.73	.902048	11.62	10	.906527	10.27	.943039	11.18
11	8.869346	10.75	8.902745	11.58	11	8.907143	10.27	8.943710	11.15
12	.869991	10.72	.903440	11.60	12	.907759	10.25	.944379	11.17
13	.870634	10.72	.904136	11.57	13	.908374	10.25	.945049	11.15
14	.871277	10.72	.904830	11.58	14	.908989	10.23	.945718	11.13
15	.871920	10.70	.905525	11.57	15	.909603	10.23	.946386	11.13
16	.872562	10.70	.906219	11.55	16	.910217	10.22	.947054	11.13
17	.873204	10.68	.906912	11.55	17	.910830	10.22	.947722	11.12
18	.873845	10.68	.907605	11.53	18	.911443	10.22	.948389	11.12
19	.874486	10.67	.908298	11.53	19	.912056	10.20	.949056	11.12
20	.875126	10.67	.908990	11.52	20	.912668	10.18	.949723	11.10
21	8.875766	10.65	8.909681	11.52	21	8.913279	10.20	8.950389	11.10
22	.876405	10.65	.910372	11.52	22	.913891	10.17	.951055	11.08
23	.877044	10.63	.911063	11.52	23	.914501	10.17	.951720	11.08
24	.877682	10.63	.911754	11.48	24	.915111	10.17	.952385	11.07
25	.878320	10.62	.912443	11.50	25	.915721	10.17	.953049	11.07
26	.878957	10.62	.913133	11.48	26	.916331	10.15	.953713	11.07
27	.879594	10.60	.913822	11.47	27	.916940	10.13	.954377	11.05
28	.880230	10.60	.914510	11.47	28	.917548	10.13	.955040	11.05
29	.880866	10.58	.915198	11.47	29	.918156	10.13	.955703	11.05
30	.881501	10.53	.915886	11.45	30	.918764	10.12	.956366	11.03
31	8.882136	10.58	8.916573	11.45	31	8.919371	10.10	8.957028	11.03
32	.882771	10.57	.917260	11.43	32	.919977	10.12	.957690	11.02
33	.883405	10.55	.917946	11.43	33	.920584	10.10	.958351	11.02
34	.884038	10.55	.918632	11.43	34	.921190	10.08	.959012	11.00
35	.884671	10.53	.919318	11.42	35	.921795	10.08	.959672	11.00
36	.885303	10.53	.920003	11.40	36	.922400	10.07	.960332	11.00
37	.885935	10.53	.920687	11.42	37	.923004	10.07	.960992	10.98
38	.886567	10.52	.921372	11.38	38	.923608	10.07	.961651	10.98
39	.887198	10.52	.922055	11.40	39	.924212	10.05	.962310	10.98
40	.887829	10.50	.922739	11.37	40	.924815	10.05	.962969	10.97
41	8.888459	10.48	8.923421	11.38	41	8.925418	10.03	8.963627	10.97
42	.889088	10.48	.924104	11.37	42	.926020	10.03	.964285	10.95
43	.889717	10.48	.924786	11.35	43	.926622	10.03	.964942	10.95
44	.890346	10.47	.925467	11.37	44	.927224	10.02	.965599	10.95
45	.890974	10.47	.926149	11.33	45	.927825	10.00	.966256	10.93
46	.891602	10.45	.926829	11.35	46	.928425	10.00	.966912	10.93
47	.892229	10.45	.927510	11.32	47	.929025	10.00	.967568	10.92
48	.892856	10.43	.928189	11.33	48	.929625	9.98	.968223	10.92
49	.893482	10.43	.928869	11.32	49	.930224	9.98	.968878	10.92
50	.894108	10.42	.929548	11.30	50	.930823	9.97	.969533	10.90
51	8.894733	10.42	8.930226	11.32	51	8.931421	9.97	8.970187	10.90
52	.895358	10.42	.930905	11.28	52	.932019	9.97	.970841	10.88
53	.895983	10.40	.931582	11.30	53	.932617	9.95	.971494	10.88
54	.896607	10.38	.932260	11.27	54	.933214	9.95	.972147	10.88
55	.897230	10.38	.932936	11.28	55	.933811	9.93	.972800	10.87
56	.897853	10.38	.933613	11.27	56	.934407	9.93	.973452	10.87
57	.898476	10.37	.934289	11.27	57	.935003	9.92	.974104	10.87
58	.899098	10.35	.934965	11.25	58	.935598	9.92	.974756	10.85
59	.899719	10.37	.935640	11.25	59	.936193	9.92	.975407	10.85
60	8.900341	10.33	8.936315	11.23	60	8.936788	9.90	8.976058	10.83

24°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	8.936788	9.90	8.976058	10.83
1	.937382	9.90	.976708	10.83
2	.937976	9.88	.977358	10.83
3	.938569	9.88	.978008	10.82
4	.939162	9.87	.978657	10.82
5	.939754	9.87	.979306	10.80
6	.940346	9.87	.979954	10.80
7	.940938	9.85	.980602	10.80
8	.941529	9.85	.981250	10.80
9	.942120	9.83	.981898	10.78
10	.942710	9.83	.982545	10.77
11	8.943300	9.82	8.983191	10.77
12	.943889	9.83	.983837	10.77
13	.944479	9.80	.984483	10.77
14	.945067	9.80	.985129	10.75
15	.945655	9.80	.985774	10.75
16	.946243	9.80	.986419	10.73
17	.946831	9.78	.987063	10.73
18	.947418	9.77	.987707	10.73
19	.948004	9.77	.988351	10.72
20	.948590	9.77	.988994	10.72
21	8.949176	9.75	8.989637	10.70
22	.949761	9.75	.990279	10.72
23	.950346	9.75	.990922	10.68
24	.950931	9.73	.991563	10.70
25	.951515	9.73	.992205	10.68
26	.952099	9.72	.992846	10.68
27	.952682	9.72	.993487	10.67
28	.953265	9.70	.994127	10.67
29	.953847	9.70	.994767	10.65
30	.954429	9.70	.995406	10.67
31	8.955011	9.68	8.996046	10.65
32	.955592	9.68	.996685	10.63
33	.956173	9.67	.997323	10.63
34	.956753	9.68	.997961	10.63
35	.957334	9.65	.998599	10.62
36	.957913	9.65	.999236	10.62
37	.958492	9.65	8.999873	10.62
38	.959071	9.65	9.000510	10.60
39	.959650	9.63	.001147	10.62
40	.960227	9.62	.001783	10.58
41	8.960805	9.62	9.002418	10.58
42	.961382	9.62	.003053	10.58
43	.961959	9.60	.003688	10.58
44	.962535	9.60	.004323	10.57
45	.963111	9.60	.004957	10.57
46	.963687	9.58	.005591	10.55
47	.964262	9.58	.006224	10.57
48	.964837	9.57	.006858	10.53
49	.965411	9.57	.007490	10.55
50	.965985	9.57	.008123	10.53
51	8.966559	9.55	9.008755	10.53
52	.967132	9.55	.009387	10.52
53	.967705	9.53	.010018	10.52
54	.968277	9.53	.010649	10.52
55	.968849	9.53	.011280	10.50
56	.969421	9.52	.011910	10.50
57	.969992	9.52	.012540	10.50
58	.970563	9.50	.013170	10.48
59	.971133	9.50	.013799	10.48
60	8.971703	9.50	9.014428	10.47

25°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	8.971703	9.50	9.014428	10.47
1	.972273	9.48	.015056	10.48
2	.972842	9.48	.015685	10.45
3	.973411	9.48	.016312	10.47
4	.973980	9.47	.016940	10.45
5	.974548	9.47	.017567	10.45
6	.975116	9.45	.018194	10.45
7	.975683	9.45	.018821	10.43
8	.976250	9.43	.019447	10.43
9	.976816	9.43	.020073	10.42
10	.977382	9.43	.020698	10.42
11	8.977948	9.43	9.021323	10.42
12	.978514	9.42	.021948	10.40
13	.979079	9.40	.022572	10.42
14	.979643	9.40	.023197	10.38
15	.980207	9.40	.023820	10.40
16	.980771	9.40	.024444	10.38
17	.981335	9.38	.025067	10.38
18	.981898	9.37	.025690	10.37
19	.982460	9.38	.026312	10.37
20	.983023	9.37	.026934	10.37
21	8.983585	9.35	9.027556	10.35
22	.984146	9.35	.028177	10.35
23	.984707	9.35	.028798	10.35
24	.985268	9.33	.029419	10.33
25	.985828	9.33	.030039	10.33
26	.986388	9.33	.030659	10.33
27	.986948	9.32	.031279	10.33
28	.987507	9.32	.031899	10.32
29	.988066	9.32	.032518	10.30
30	.988625	9.30	.033136	10.32
31	8.989183	9.28	9.033755	10.30
32	.989740	9.30	.034373	10.30
33	.990298	9.28	.034991	10.28
34	.990855	9.27	.035608	10.28
35	.991411	9.28	.036225	10.28
36	.991968	9.25	.036842	10.27
37	.992523	9.27	.037458	10.27
38	.993079	9.25	.038074	10.27
39	.993634	9.25	.038690	10.25
40	.994189	9.23	.039305	10.25
41	8.994743	9.23	9.039920	10.25
42	.995297	9.23	.040535	10.25
43	.995851	9.22	.041150	10.23
44	.996404	9.22	.041764	10.23
45	.996957	9.20	.042378	10.22
46	.997509	9.22	.042991	10.22
47	.998062	9.18	.043604	10.22
48	.998613	9.20	.044217	10.22
49	.999165	9.18	.044830	10.20
50	8.999716	9.17	.045442	10.20
51	9.000266	9.18	9.046054	10.16
52	.000817	9.17	.046665	10.18
53	.001367	9.15	.047276	10.18
54	.001916	9.17	.047887	10.18
55	.002466	9.13	.048498	10.17
56	.003014	9.15	.049108	10.17
57	.003563	9.13	.049718	10.17
58	.004111	9.13	.050328	10.15
59	.004659	9.12	.050937	10.15
60	9.005206	9.12	9.051546	10.15

26°					27°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.005206	9.12	9.051546	10.15	0	9.037401	8.77	9.087520	9.83
1	.005753	9.12	.052155	10.13	1	.037927	8.75	.088110	9.83
2	.006300	9.10	.052763	10.13	2	.038452	8.77	.088700	9.83
3	.006846	9.10	.053371	10.13	3	.038978	8.75	.089290	9.83
4	.007392	9.10	.053979	10.12	4	.039503	8.73	.089880	9.82
5	.007938	9.08	.054586	10.12	5	.040027	8.75	.090469	9.82
6	.008483	9.08	.055193	10.12	6	.040552	8.73	.091058	9.82
7	.009028	9.07	.055800	10.10	7	.041076	8.72	.091647	9.80
8	.009572	9.07	.056406	10.10	8	.041599	8.73	.092235	9.80
9	.010116	9.07	.057012	10.10	9	.042123	8.72	.092823	9.80
10	.010660	9.05	.057618	10.10	10	.042646	8.70	.093411	9.78
11	9.011203	9.05	9.058224	10.08	11	9.043168	8.72	9.093998	9.80
12	.011746	9.05	.058829	10.08	12	.043691	8.70	.094586	9.78
13	.012289	9.03	.059434	10.07	13	.044213	8.70	.095173	9.77
14	.012831	9.03	.060038	10.08	14	.044735	8.68	.095759	9.78
15	.013373	9.03	.060643	10.07	15	.045256	8.68	.096346	9.77
16	.013915	9.02	.061247	10.05	16	.045777	8.68	.096932	9.77
17	.014456	9.02	.061850	10.07	17	.046298	8.67	.097518	9.75
18	.014997	9.02	.062454	10.05	18	.046818	8.67	.098103	9.77
19	.015538	9.00	.063057	10.03	19	.047338	8.67	.098689	9.75
20	.016078	9.00	.063659	10.05	20	.047858	8.65	.099274	9.73
21	9.016618	8.98	9.064262	10.03	21	9.048377	8.65	9.099858	9.75
22	.017157	9.00	.064864	10.03	22	.048896	8.65	.100443	9.73
23	.017697	8.97	.065466	10.02	23	.049415	8.63	.101027	9.73
24	.018235	8.98	.066067	10.02	24	.049933	8.63	.101611	9.72
25	.018774	8.97	.066668	10.02	25	.050451	8.63	.102194	9.73
26	.019312	8.97	.067269	10.02	26	.050969	8.63	.102778	9.72
27	.019850	8.95	.067870	10.00	27	.051487	8.62	.103361	9.70
28	.020387	8.95	.068470	10.00	28	.052004	8.60	.103943	9.72
29	.020924	8.95	.069070	10.00	29	.052520	8.62	.104526	9.70
30	.021461	8.93	.069670	9.98	30	.053037	8.60	.105108	9.70
31	9.021997	8.93	9.070269	9.98	31	9.053553	8.60	9.105690	9.68
32	.022533	8.93	.070868	9.98	32	.054069	8.58	.106271	9.70
33	.023069	8.92	.071467	9.97	33	.054584	8.58	.106853	9.68
34	.023604	8.92	.072065	9.97	34	.055099	8.58	.107434	9.68
35	.024139	8.90	.072663	9.97	35	.055614	8.58	.108015	9.67
36	.024673	8.92	.073261	9.97	36	.056129	8.57	.108595	9.67
37	.025208	8.90	.073859	9.95	37	.056643	8.57	.109175	9.67
38	.025742	8.88	.074456	9.95	38	.057157	8.55	.109755	9.67
39	.026275	8.88	.075053	9.93	39	.057670	8.55	.110335	9.65
40	.026808	8.88	.075649	9.95	40	.058183	8.55	.110914	9.67
41	9.027341	8.88	9.076246	9.93	41	9.058696	8.55	9.111494	9.63
42	.027874	8.87	.076842	9.92	42	.059209	8.53	.112072	9.65
43	.028406	8.87	.077437	9.93	43	.059721	8.53	.112651	9.63
44	.028938	8.85	.078033	9.92	44	.060233	8.53	.113229	9.63
45	.029469	8.85	.078628	9.92	45	.060745	8.52	.113807	9.63
46	.030000	8.85	.079223	9.90	46	.061256	8.52	.114385	9.63
47	.030531	8.85	.079817	9.92	47	.061767	8.50	.114963	9.62
48	.031062	8.83	.080412	9.90	48	.062277	8.52	.115540	9.62
49	.031592	8.83	.081006	9.88	49	.062788	8.50	.116117	9.60
50	.032122	8.82	.081599	9.90	50	.063298	8.48	.116693	9.62
51	9.032651	8.82	9.082193	9.88	51	9.063807	8.50	9.117270	9.60
52	.033180	8.82	.082786	9.87	52	.064317	8.48	.117846	9.60
53	.033709	8.80	.083378	9.88	53	.064826	8.48	.118422	9.58
54	.034237	8.80	.083971	9.87	54	.065335	8.47	.118997	9.60
55	.034765	8.80	.084563	9.87	55	.065843	8.47	.119573	9.58
56	.035293	8.78	.085155	9.87	56	.066351	8.47	.120148	9.58
57	.035820	8.78	.085747	9.85	57	.066859	8.45	.120723	9.57
58	.036347	8.78	.086338	9.85	58	.067366	8.47	.121297	9.57
59	.036874	8.78	.086929	9.85	59	.067874	8.43	.121871	9.57
60	9.037401	8.77	9.087520	9.83	60	9.068380	8.45	9.122445	9.57

28°

	Vers.	D. 1°.	Ex. sec.	D. 1°.
0	9.068380	8.45	9.122445	9.57
1	.068887	8.43	.123019	9.57
2	.069393	8.43	.123593	9.55
3	.069899	8.43	.124166	9.55
4	.070405	8.42	.124739	9.53
5	.070910	8.42	.125311	9.55
6	.071415	8.40	.125884	9.53
7	.071919	8.42	.126456	9.53
8	.072424	8.40	.127028	9.52
9	.072928	8.40	.127599	9.53
10	.073432	8.38	.128171	9.52
11	9.073935	8.38	9.128742	9.52
12	.074438	8.38	.129313	9.50
13	.074941	8.37	.129883	9.50
14	.075443	8.38	.130453	9.50
15	.075946	8.35	.131023	9.50
16	.076447	8.37	.131593	9.50
17	.076949	8.35	.132163	9.48
18	.077450	8.35	.132732	9.48
19	.077951	8.35	.133301	9.48
20	.078452	8.33	.133870	9.47
21	9.078952	8.33	9.134438	9.47
22	.079452	8.33	.135006	9.47
23	.079952	8.32	.135574	9.47
24	.080451	8.32	.136142	9.45
25	.080950	8.32	.136709	9.47
26	.081449	8.32	.137277	9.45
27	.081948	8.30	.137844	9.43
28	.082446	8.30	.138410	9.45
29	.082944	8.28	.138977	9.43
30	.083441	8.30	.139543	9.43
31	9.083939	8.28	9.140109	9.42
32	.084436	8.27	.140674	9.43
33	.084932	8.28	.141240	9.42
34	.085429	8.27	.141805	9.42
35	.085925	8.25	.142370	9.40
36	.086420	8.27	.142934	9.42
37	.086916	8.25	.143499	9.40
38	.087411	8.25	.144063	9.40
39	.087906	8.23	.144627	9.38
40	.088400	8.25	.145190	9.40
41	9.088895	8.23	9.145754	9.38
42	.089389	8.22	.146317	9.38
43	.089882	8.23	.146880	9.37
44	.090376	8.22	.147442	9.38
45	.090869	8.22	.148005	9.37
46	.091362	8.20	.148567	9.37
47	.091854	8.20	.149129	9.35
48	.092346	8.20	.149690	9.35
49	.092838	8.20	.150251	9.37
50	.093330	8.18	.150812	9.33
51	9.093821	8.18	9.151373	9.35
52	.094312	8.18	.151934	9.33
53	.094803	8.17	.152494	9.35
54	.095293	8.17	.153055	9.32
55	.095783	8.17	.153614	9.33
56	.096273	8.17	.154174	9.32
57	.096763	8.15	.154733	9.33
58	.097252	8.15	.155293	9.30
59	.097741	8.13	.155851	9.32
60	9.098229	8.15	9.156410	9.30

29°

	Vers.	D. 1°.	Ex. sec.	D. 1°.
0	9.098229	8.15	9.156410	9.30
1	.098718	8.13	.156968	9.32
2	.099206	8.12	.157527	9.28
3	.099693	8.13	.158084	9.30
4	.100181	8.12	.158642	9.30
5	.100668	8.12	.159200	9.28
6	.101155	8.12	.159757	9.28
7	.101642	8.10	.160314	9.27
8	.102128	8.10	.160870	9.28
9	.102614	8.10	.161427	9.27
10	.103100	8.08	.161983	9.27
11	9.103585	8.08	9.162539	9.27
12	.104070	8.08	.163095	9.25
13	.104555	8.08	.163650	9.25
14	.105040	8.07	.164205	9.25
15	.105524	8.07	.164760	9.25
16	.106008	8.05	.165315	9.25
17	.106491	8.07	.165870	9.23
18	.106975	8.05	.166424	9.23
19	.107458	8.05	.166978	9.23
20	.107941	8.03	.167532	9.22
21	9.108423	8.05	9.168085	9.23
22	.108906	8.03	.168639	9.22
23	.109388	8.02	.169192	9.22
24	.109869	8.03	.169745	9.20
25	.110351	8.02	.170297	9.22
26	.110832	8.02	.170850	9.20
27	.111313	8.00	.171402	9.20
28	.111793	8.00	.171954	9.18
29	.112273	8.00	.172505	9.20
30	.112753	8.00	.173057	9.18
31	9.113233	8.00	9.173608	9.18
32	.113713	7.98	.174159	9.18
33	.114192	7.98	.174710	9.17
34	.114671	7.97	.175260	9.17
35	.115149	7.97	.175810	9.17
36	.115627	7.97	.176360	9.17
37	.116105	7.97	.176910	9.17
38	.116583	7.97	.177460	9.15
39	.117061	7.95	.178009	9.15
40	.117538	7.95	.178558	9.15
41	9.118015	7.98	9.179107	9.15
42	.118491	7.95	.179656	9.13
43	.118968	7.93	.180204	9.13
44	.119444	7.92	.180752	9.13
45	.119919	7.93	.181300	9.13
46	.120395	7.92	.181848	9.12
47	.120870	7.92	.182395	9.13
48	.121345	7.92	.182943	9.12
49	.121820	7.90	.183490	9.10
50	.122294	7.90	.184036	9.12
51	9.122768	7.90	9.184583	9.10
52	.123242	7.88	.185129	9.10
53	.123715	7.90	.185675	9.10
54	.124189	7.88	.186221	9.10
55	.124662	7.87	.186767	9.08
56	.125134	7.88	.187312	9.10
57	.125607	7.87	.187858	9.08
58	.126079	7.87	.188403	9.07
59	.126551	7.85	.188947	9.08
60	9.127022	7.87	9.189492	9.07

30°					31°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.127022	7.87	9.189492	9.07	0	9.154828	7.58	9.221762	8.85
1	.127494	7.85	.190036	9.07	1	.155283	7.58	.222293	8.87
2	.127965	7.85	.190580	9.07	2	.155738	7.58	.222825	8.83
3	.128436	7.83	.191124	9.07	3	.156193	7.58	.223355	8.85
4	.128906	7.83	.191668	9.05	4	.156648	7.57	.223886	8.85
5	.129376	7.83	.192211	9.05	5	.157102	7.57	.224417	8.83
6	.129846	7.83	.192754	9.05	6	.157556	7.57	.224947	8.83
7	.130316	7.82	.193297	9.05	7	.158010	7.57	.225477	8.83
8	.130785	7.83	.193840	9.03	8	.158464	7.55	.226007	8.83
9	.131255	7.82	.194382	9.05	9	.158917	7.55	.226537	8.82
10	.131724	7.80	.194925	9.03	10	.159370	7.55	.227066	8.82
11	9.132192	7.80	9.195467	9.03	11	9.159823	7.55	9.227595	8.83
12	.132660	7.82	.196009	9.02	12	.160276	7.53	.228125	8.80
13	.133129	7.78	.196550	9.03	13	.160728	7.53	.228653	8.82
14	.133596	7.80	.197092	9.02	14	.161180	7.53	.229182	8.82
15	.134064	7.78	.197633	9.02	15	.161632	7.52	.229711	8.80
16	.134531	7.78	.198174	9.02	16	.162083	7.53	.230239	8.80
17	.134998	7.78	.198715	9.00	17	.162535	7.52	.230767	8.80
18	.135465	7.77	.199255	9.00	18	.162986	7.52	.231295	8.78
19	.135931	7.77	.199795	9.00	19	.163437	7.50	.231822	8.80
20	.136397	7.77	.200335	9.00	20	.163887	7.52	.232350	8.78
21	9.136863	7.77	9.200875	9.00	21	9.164338	7.50	9.232877	8.78
22	.137329	7.75	.201415	8.98	22	.164788	7.48	.233404	8.78
23	.137794	7.77	.201954	9.00	23	.165237	7.50	.233931	8.78
24	.138260	7.73	.202494	8.97	24	.165687	7.48	.234458	8.77
25	.138724	7.75	.203033	8.98	25	.166136	7.48	.234984	8.77
26	.139189	7.73	.203571	8.98	26	.166585	7.48	.235510	8.77
27	.139653	7.73	.204110	8.97	27	.167034	7.48	.236036	8.77
28	.140117	7.73	.204648	8.97	28	.167483	7.47	.236562	8.77
29	.140581	7.73	.205186	8.97	29	.167931	7.47	.237088	8.75
30	.141045	7.72	.205724	8.97	30	.168379	7.47	.237613	8.77
31	9.141508	7.72	9.206262	8.95	31	9.168827	7.47	9.238139	8.75
32	.141971	7.72	.206799	8.97	32	.169275	7.45	.238664	8.75
33	.142434	7.70	.207337	8.95	33	.169722	7.45	.239189	8.73
34	.142896	7.70	.207874	8.93	34	.170169	7.45	.239713	8.75
35	.143358	7.70	.208410	8.95	35	.170616	7.43	.240238	8.73
36	.143820	7.70	.208947	8.93	36	.171062	7.45	.240762	8.73
37	.144282	7.68	.209483	8.95	37	.171509	7.43	.241286	8.73
38	.144743	7.68	.210020	8.93	38	.171955	7.42	.241810	8.72
39	.145204	7.68	.210556	8.92	39	.172400	7.43	.242333	8.73
40	.145665	7.68	.211091	8.93	40	.172846	7.42	.242857	8.72
41	9.146126	7.67	9.211627	8.92	41	9.173291	7.42	9.243380	8.72
42	.146586	7.67	.212162	8.92	42	.173736	7.42	.243903	8.72
43	.147046	7.67	.212697	8.92	43	.174181	7.42	.244426	8.72
44	.147506	7.67	.213232	8.92	44	.174626	7.40	.244949	8.70
45	.147966	7.65	.213767	8.90	45	.175070	7.40	.245471	8.72
46	.148425	7.65	.214301	8.92	46	.175514	7.40	.245994	8.70
47	.148884	7.65	.214836	8.90	47	.175958	7.40	.246516	8.70
48	.149343	7.63	.215370	8.90	48	.176402	7.38	.247038	8.68
49	.149801	7.63	.215904	8.88	49	.176845	7.38	.247559	8.70
50	.150259	7.63	.216437	8.90	50	.177288	7.38	.248081	8.68
51	9.150717	7.63	9.216971	8.88	51	9.177731	7.38	9.248602	8.68
52	.151175	7.63	.217504	8.88	52	.178174	7.37	.249123	8.68
53	.151633	7.62	.218037	8.88	53	.178616	7.37	.249644	8.68
54	.152090	7.62	.218570	8.87	54	.179058	7.37	.250165	8.68
55	.152547	7.60	.219102	8.88	55	.179500	7.37	.250686	8.67
56	.153003	7.62	.219635	8.87	56	.179942	7.35	.251206	8.67
57	.153460	7.60	.220167	8.87	57	.180383	7.37	.251726	8.67
58	.153916	7.60	.220699	8.87	58	.180825	7.33	.252246	8.67
59	.154372	7.60	.221231	8.85	59	.181265	7.35	.252766	8.67
60	9.154828	7.58	9.221762	8.85	60	9.181706	7.35	9.253286	8.65

32°					33°				
	Vers.	D. 1".	Ex. sec.	D. 1".		Vers.	D. 1".	Ex. sec.	D. 1".
0	9.181706	7.35	9.253286	8.65	0	9.207714	7.10	9.284122	8.48
1	.182147	7.33	.253805	8.65	1	.208140	7.10	.284631	8.47
2	.182587	7.33	.254324	8.65	2	.208566	7.10	.285139	8.47
3	.183027	7.32	.254843	8.65	3	.208992	7.10	.285647	8.47
4	.183466	7.33	.255362	8.65	4	.209418	7.08	.286155	8.47
5	.183906	7.32	.255881	8.63	5	.209843	7.08	.286663	8.45
6	.184345	7.32	.256399	8.65	6	.210268	7.08	.287170	8.47
7	.184784	7.32	.256918	8.63	7	.210693	7.08	.287678	8.45
8	.185223	7.32	.257436	8.63	8	.211118	7.08	.288185	8.45
9	.185662	7.30	.257954	8.62	9	.211543	7.07	.288692	8.45
10	.186100	7.30	.258471	8.63	10	.211967	7.07	.289199	8.43
11	9.186538	7.30	9.258989	8.62	11	9.212391	7.07	9.289705	8.45
12	.186976	7.28	.259506	8.62	12	.212815	7.07	.290212	8.43
13	.187413	7.30	.260023	8.62	13	.213239	7.05	.290718	8.43
14	.187851	7.28	.260540	8.62	14	.213662	7.05	.291224	8.43
15	.188288	7.27	.261057	8.62	15	.214085	7.05	.291730	8.43
16	.188724	7.28	.261574	8.60	16	.214508	7.05	.292236	8.43
17	.189161	7.27	.262090	8.60	17	.214931	7.05	.292742	8.42
18	.189597	7.28	.262606	8.60	18	.215354	7.03	.293247	8.43
19	.190034	7.25	.263122	8.60	19	.215776	7.03	.293753	8.42
20	.190469	7.27	.263638	8.60	20	.216198	7.03	.294258	8.42
21	9.190905	7.27	9.264154	8.58	21	9.216620	7.03	9.294763	8.42
22	.191341	7.25	.264669	8.58	22	.217042	7.02	.295268	8.40
23	.191776	7.25	.265184	8.60	23	.217463	7.02	.295772	8.42
24	.192211	7.23	.265700	8.57	24	.217884	7.02	.296277	8.40
25	.192645	7.25	.266214	8.58	25	.218305	7.02	.296781	8.40
26	.193080	7.23	.266729	8.58	26	.218726	7.00	.297285	8.40
27	.193514	7.23	.267244	8.57	27	.219146	7.02	.297789	8.40
28	.193948	7.23	.267758	8.57	28	.219567	7.00	.298293	8.40
29	.194382	7.22	.268272	8.57	29	.219987	7.00	.298797	8.38
30	.194815	7.23	.268786	8.57	30	.220407	6.98	.299300	8.38
31	9.195249	7.22	9.269300	8.57	31	9.220826	7.00	9.299803	8.40
32	.195682	7.22	.269814	8.55	32	.221246	6.98	.300307	8.37
33	.196115	7.20	.270327	8.55	33	.221665	6.98	.300809	8.38
34	.196547	7.22	.270840	8.57	34	.222084	6.98	.301312	8.38
35	.196980	7.20	.271354	8.53	35	.222503	6.97	.301815	8.37
36	.197412	7.20	.271866	8.55	36	.222921	6.98	.302317	8.38
37	.197844	7.18	.272379	8.55	37	.223340	6.97	.302820	8.37
38	.198275	7.20	.272892	8.53	38	.223758	6.97	.303322	8.37
39	.198707	7.18	.273404	8.53	39	.224176	6.95	.303824	8.35
40	.199138	7.18	.273916	8.53	40	.224593	6.97	.304325	8.37
41	9.199569	7.18	9.274428	8.53	41	9.225011	6.95	9.304827	8.35
42	.200000	7.17	.274940	8.53	42	.225428	6.95	.305328	8.37
43	.200430	7.18	.275452	8.52	43	.225845	6.95	.305830	8.35
44	.200861	7.17	.275963	8.52	44	.226262	6.93	.306331	8.35
45	.201291	7.15	.276474	8.53	45	.226678	6.95	.306832	8.35
46	.201720	7.17	.276986	8.50	46	.227095	6.93	.307333	8.33
47	.202150	7.15	.277496	8.52	47	.227511	6.93	.307833	8.35
48	.202579	7.15	.278007	8.52	48	.227927	6.92	.308334	8.33
49	.203008	7.15	.278518	8.50	49	.228342	6.93	.308834	8.33
50	.203437	7.15	.279028	8.50	50	.228758	6.92	.309334	8.33
51	9.203866	7.13	9.279538	8.50	51	9.229173	6.92	9.309834	8.33
52	.204294	7.15	.280048	8.50	52	.229588	6.92	.310334	8.33
53	.204723	7.13	.280558	8.50	53	.230003	6.92	.310834	8.32
54	.205151	7.12	.281068	8.48	54	.230418	6.90	.311333	8.32
55	.205578	7.13	.281577	8.50	55	.230832	6.90	.311832	8.32
56	.206006	7.13	.282087	8.48	56	.231246	6.90	.312331	8.32
57	.206433	7.12	.282596	8.48	57	.231660	6.90	.312830	8.32
58	.206860	7.12	.283105	8.48	58	.232074	6.88	.313329	8.32
59	.207287	7.12	.283614	8.47	59	.232487	6.90	.313828	8.30
60	9.207714	7.10	9.284122	8.48	60	9.232901	6.88	9.314326	8.32

34°					35°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.232901	6.88	9.314326	8.32	0	9.257314	6.67	9.343949	8.15
1	.233314	6.88	.314825	8.30	1	.257714	6.68	.344438	8.15
2	.233727	6.87	.315323	8.30	2	.258115	6.67	.344927	8.15
3	.234139	6.88	.315821	8.30	3	.258515	6.67	.345416	8.13
4	.234552	6.87	.316319	8.30	4	.258915	6.65	.345904	8.15
5	.234964	6.87	.316817	8.28	5	.259314	6.67	.346393	8.13
6	.235376	6.87	.317314	8.28	6	.259714	6.65	.346881	8.13
7	.235788	6.85	.317811	8.30	7	.260113	6.65	.347369	8.13
8	.236199	6.87	.318309	8.28	8	.260512	6.65	.347857	8.13
9	.236611	6.85	.318806	8.28	9	.260911	6.65	.348345	8.13
10	.237022	6.85	.319303	8.27	10	.261310	6.65	.348833	8.13
11	9.237433	6.85	9.319799	8.28	11	9.261709	6.63	9.349321	8.12
12	.237844	6.83	.320296	8.27	12	.262107	6.63	.349808	8.12
13	.238254	6.85	.320792	8.28	13	.262505	6.63	.350295	8.12
14	.238665	6.83	.321289	8.27	14	.262903	6.63	.350782	8.12
15	.239075	6.83	.321785	8.27	15	.263301	6.62	.351269	8.12
16	.239485	6.82	.322281	8.25	16	.263698	6.63	.351756	8.12
17	.239894	6.83	.322776	8.27	17	.264096	6.62	.352243	8.12
18	.240304	6.82	.323272	8.27	18	.264493	6.62	.352730	8.10
19	.240713	6.82	.323768	8.25	19	.264890	6.62	.353216	8.10
20	.241122	6.82	.324263	8.25	20	.265287	6.60	.353702	8.10
21	9.241531	6.82	9.324758	8.25	21	9.265683	6.62	9.354188	8.10
22	.241940	6.82	.325253	8.25	22	.266080	6.60	.354674	8.10
23	.242348	6.80	.325748	8.25	23	.266476	6.60	.355160	8.10
24	.242756	6.80	.326243	8.23	24	.266872	6.58	.355646	8.08
25	.243164	6.80	.326737	8.25	25	.267267	6.60	.356131	8.10
26	.243572	6.80	.327232	8.23	26	.267663	6.58	.356617	8.08
27	.243980	6.78	.327726	8.23	27	.268058	6.58	.357102	8.08
28	.244387	6.78	.328220	8.23	28	.268453	6.58	.357587	8.08
29	.244794	6.78	.328714	8.22	29	.268848	6.58	.358072	8.08
30	.245201	6.78	.329207	8.23	30	.269243	6.58	.358557	8.08
31	9.245608	6.77	9.329701	8.23	31	9.269638	6.57	9.359042	8.07
32	.246014	6.78	.330195	8.22	32	.270032	6.57	.359526	8.08
33	.246421	6.77	.330688	8.22	33	.270426	6.57	.360011	8.07
34	.246827	6.77	.331181	8.22	34	.270820	6.57	.360495	8.07
35	.247233	6.77	.331674	8.22	35	.271214	6.57	.360979	8.07
36	.247639	6.75	.332167	8.20	36	.271608	6.55	.361463	8.07
37	.248044	6.75	.332659	8.22	37	.272001	6.55	.361947	8.07
38	.248449	6.75	.333152	8.20	38	.272394	6.55	.362431	8.05
39	.248854	6.75	.333644	8.22	39	.272787	6.55	.362914	8.07
40	.249259	6.75	.334137	8.20	40	.273180	6.53	.363398	8.05
41	9.249664	6.73	9.334629	8.20	41	9.273572	6.55	9.363881	8.05
42	.250068	6.75	.335121	8.18	42	.273965	6.53	.364364	8.05
43	.250473	6.73	.335612	8.20	43	.274357	6.53	.364847	8.05
44	.250877	6.73	.336104	8.18	44	.274749	6.53	.365330	8.05
45	.251281	6.72	.336595	8.20	45	.275141	6.52	.365813	8.03
46	.251684	6.73	.337087	8.18	46	.275532	6.53	.366295	8.05
47	.252088	6.72	.337578	8.18	47	.275924	6.52	.366778	8.03
48	.252491	6.72	.338069	8.18	48	.276315	6.52	.367260	8.03
49	.252894	6.72	.338560	8.17	49	.276706	6.52	.367742	8.03
50	.253297	6.70	.339050	8.18	50	.277097	6.52	.368224	8.03
51	9.253699	6.72	9.339541	8.17	51	9.277488	6.50	9.368706	8.03
52	.254102	6.70	.340031	8.18	52	.277878	6.50	.369188	8.03
53	.254504	6.70	.340522	8.17	53	.278268	6.50	.369670	8.02
54	.254906	6.70	.341012	8.17	54	.278658	6.50	.370151	8.02
55	.255308	6.68	.341502	8.15	55	.279048	6.50	.370632	8.03
56	.255709	6.70	.341991	8.17	56	.279438	6.48	.371114	8.02
57	.256111	6.68	.342481	8.17	57	.279827	6.50	.371595	8.02
58	.256512	6.68	.342971	8.15	58	.280217	6.48	.372076	8.00
59	.256913	6.68	.343460	8.15	59	.280606	6.48	.372556	8.02
60	9.257314	6.67	9.343949	8.15	60	9.280995	6.47	9.373037	8.02

36°

37°

	Vers.	D. 1°.	Ex. sec.	D. 1°.		Vers.	D. 1°.	Ex. sec.	D. 1°.
0	9.280995	6.47	9.373037	8.02	0	9.303983	6.28	9.401634	7.88
1	.281383	6.48	.373518	8.00	1	.304360	6.30	.402107	7.88
2	.281772	6.47	.373998	8.00	2	.304738	6.28	.402580	7.87
3	.282160	6.47	.374478	8.00	3	.305115	6.28	.403052	7.87
4	.282548	6.47	.374958	8.00	4	.305492	6.27	.403524	7.88
5	.282936	6.47	.375438	8.00	5	.305868	6.28	.403997	7.88
6	.283324	6.47	.375918	8.00	6	.306245	6.27	.404469	7.87
7	.283712	6.45	.376398	7.98	7	.306621	6.28	.404941	7.87
8	.284099	6.45	.376877	8.00	8	.306998	6.27	.405412	7.87
9	.284486	6.45	.377357	7.98	9	.307374	6.25	.405884	7.87
10	.284873	6.45	.377836	7.98	10	.307749	6.27	.406356	7.85
11	9.285260	6.45	9.378315	7.98	11	9.308125	6.27	9.406827	7.85
12	.285647	6.43	.378794	7.98	12	.308501	6.25	.407298	7.87
13	.286033	6.43	.379273	7.98	13	.308876	6.25	.407770	7.85
14	.286419	6.43	.379752	7.98	14	.309251	6.25	.408241	7.85
15	.286805	6.43	.380231	7.97	15	.309626	6.25	.408712	7.85
16	.287191	6.43	.380709	7.98	16	.310001	6.23	.409183	7.83
17	.287577	6.42	.381188	7.97	17	.310375	6.25	.409653	7.85
18	.287962	6.43	.381666	7.97	18	.310750	6.23	.410124	7.83
19	.288348	6.42	.382144	7.97	19	.311124	6.23	.410594	7.85
20	.288733	6.42	.382622	7.97	20	.311498	6.23	.411065	7.88
21	9.289118	6.40	9.383100	7.95	21	9.311872	6.22	9.411535	7.83
22	.289502	6.42	.383577	7.97	22	.312245	6.23	.412005	7.83
23	.289887	6.40	.384055	7.95	23	.312619	6.22	.412475	7.83
24	.290271	6.40	.384532	7.97	24	.312992	6.22	.412945	7.83
25	.290655	6.40	.385010	7.95	25	.313365	6.22	.413415	7.82
26	.291039	6.40	.385487	7.95	26	.313738	6.22	.413884	7.83
27	.291423	6.40	.385964	7.95	27	.314111	6.22	.414354	7.82
28	.291807	6.38	.386441	7.95	28	.314484	6.20	.414823	7.83
29	.292190	6.38	.386918	7.93	29	.314856	6.20	.415293	7.82
30	.292573	6.38	.387394	7.95	30	.315228	6.20	.415762	7.82
31	9.292956	6.38	9.387871	7.93	31	9.315600	6.20	9.416231	7.82
32	.293339	6.38	.388347	7.95	32	.315972	6.20	.416700	7.80
33	.293722	6.37	.388824	7.93	33	.316344	6.20	.417168	7.82
34	.294104	6.37	.389300	7.93	34	.316716	6.18	.417637	7.82
35	.294486	6.37	.389776	7.93	35	.317087	6.18	.418106	7.80
36	.294868	6.37	.390252	7.92	36	.317458	6.18	.418574	7.80
37	.295250	6.37	.390727	7.93	37	.317829	6.18	.419042	7.82
38	.295632	6.37	.391203	7.92	38	.318200	6.18	.419511	7.80
39	.296014	6.35	.391678	7.93	39	.318571	6.17	.419979	7.80
40	.296395	6.35	.392154	7.92	40	.318941	6.17	.420447	7.80
41	9.296776	6.35	9.392629	7.92	41	9.319311	6.18	9.420915	7.78
42	.297157	6.35	.393104	7.92	42	.319682	6.15	.421382	7.80
43	.297538	6.33	.393579	7.92	43	.320051	6.17	.421850	7.78
44	.297918	6.35	.394054	7.92	44	.320421	6.17	.422317	7.80
45	.298299	6.33	.394529	7.90	45	.320791	6.15	.422785	7.78
46	.298679	6.33	.395003	7.92	46	.321160	6.17	.423252	7.78
47	.299059	6.33	.395478	7.90	47	.321530	6.15	.423719	7.78
48	.299439	6.33	.395952	7.90	48	.321899	6.13	.424186	7.78
49	.299819	6.32	.396426	7.90	49	.322267	6.15	.424653	7.78
50	.300198	6.32	.396900	7.90	50	.322636	6.15	.425120	7.78
51	9.300577	6.33	9.397374	7.90	51	9.323005	6.13	9.425587	7.77
52	.300957	6.30	.397848	7.90	52	.323373	6.13	.426053	7.78
53	.301335	6.32	.398322	7.88	53	.323741	6.13	.426520	7.77
54	.301714	6.32	.398795	7.90	54	.324109	6.13	.426986	7.77
55	.302093	6.30	.399269	7.88	55	.324477	6.13	.427452	7.77
56	.302471	6.30	.399742	7.88	56	.324845	6.12	.427918	7.77
57	.302849	6.30	.400215	7.88	57	.325212	6.13	.428384	7.77
58	.303227	6.30	.400688	7.88	58	.325580	6.12	.428850	7.77
59	.303605	6.30	.401161	7.88	59	.325947	6.12	.429316	7.77
60	9.303983	6.28	9.401634	7.88	60	9.326314	6.12	9.429782	7.76

38°					39°				
°	Vers.	D. 1".	Ex. sec.	D. 1"	'	Vers.	D. 1".	Ex. sec.	D. 1".
0	9.326314	6.12	9.429782	7.75	0	9.348021	5.93	9.457518	7.65
1	.326681	6.10	.430247	7.77	1	.348377	5.95	.457977	7.65
2	.327047	6.12	.430713	7.75	2	.348734	5.93	.458436	7.65
3	.327414	6.10	.431178	7.75	3	.349090	5.93	.458895	7.63
4	.327780	6.10	.431643	7.75	4	.349446	5.93	.459353	7.65
5	.328146	6.10	.432108	7.75	5	.349802	5.93	.459812	7.63
6	.328512	6.10	.432573	7.75	6	.350158	5.93	.460270	7.65
7	.328878	6.08	.433038	7.75	7	.350514	5.92	.460729	7.63
8	.329243	6.10	.433503	7.73	8	.350869	5.93	.461187	7.63
9	.329609	6.08	.433967	7.75	9	.351225	5.92	.461645	7.63
10	.329974	6.08	.434432	7.73	10	.351580	5.92	.462103	7.63
11	9.330339	6.08	9.434896	7.75	11	9.351935	5.92	9.462561	7.63
12	.330704	6.08	.435361	7.73	12	.352290	5.90	.463019	7.63
13	.331069	6.07	.435825	7.73	13	.352644	5.92	.463477	7.62
14	.331433	6.08	.436289	7.73	14	.352999	5.90	.463934	7.63
15	.331798	6.07	.436753	7.73	15	.353353	5.90	.464392	7.62
16	.332162	6.07	.437217	7.72	16	.353707	5.92	.464849	7.63
17	.332526	6.07	.437680	7.73	17	.354062	5.88	.465307	7.62
18	.332890	6.07	.438144	7.73	18	.354415	5.90	.465764	7.62
19	.333254	6.05	.438608	7.72	19	.354769	5.90	.466221	7.62
20	.333617	6.07	.439071	7.72	20	.355123	5.88	.466678	7.62
21	9.333981	6.05	9.439534	7.72	21	9.355476	5.88	9.467135	7.62
22	.334344	6.05	.439997	7.72	22	.355829	5.88	.467592	7.62
23	.334707	6.05	.440460	7.72	23	.356182	5.88	.468049	7.62
24	.335070	6.03	.440923	7.72	24	.356535	5.88	.468506	7.60
25	.335432	6.05	.441386	7.72	25	.356888	5.88	.468962	7.60
26	.335795	6.03	.441849	7.72	26	.357241	5.87	.469418	7.62
27	.336157	6.03	.442312	7.70	27	.357593	5.87	.469875	7.60
28	.336519	6.03	.442774	7.72	28	.357945	5.87	.470331	7.60
29	.336881	6.03	.443237	7.70	29	.358297	5.87	.470787	7.60
30	.337243	6.03	.443699	7.70	30	.358649	5.87	.471243	7.60
31	9.337605	6.02	9.444161	7.70	31	9.359001	5.87	9.471699	7.60
32	.337966	6.03	.444623	7.70	32	.359353	5.85	.472155	7.60
33	.338328	6.02	.445085	7.70	33	.359704	5.87	.472611	7.60
34	.338689	6.02	.445547	7.70	34	.360056	5.85	.473067	7.58
35	.339050	6.02	.446009	7.68	35	.360407	5.85	.473522	7.60
36	.339411	6.00	.446470	7.70	36	.360758	5.83	.473978	7.58
37	.339771	6.02	.446932	7.68	37	.361108	5.85	.474433	7.58
38	.340132	6.00	.447393	7.70	38	.361459	5.85	.474888	7.58
39	.340492	6.00	.447855	7.68	39	.361810	5.83	.475343	7.58
40	.340852	6.00	.448316	7.68	40	.362160	5.83	.475798	7.58
41	9.341212	6.00	9.448777	7.68	41	9.362510	5.83	9.476253	7.58
42	.341572	6.00	.449238	7.68	42	.362860	5.83	.476708	7.58
43	.341932	5.98	.449699	7.68	43	.363210	5.83	.477163	7.58
44	.342291	6.00	.450160	7.67	44	.363560	5.82	.477618	7.57
45	.342651	5.98	.450620	7.68	45	.363909	5.83	.478072	7.58
46	.343010	5.98	.451081	7.67	46	.364259	5.82	.478527	7.57
47	.343369	5.98	.451541	7.68	47	.364608	5.82	.478981	7.57
48	.343728	5.97	.452002	7.67	48	.364957	5.82	.479435	7.58
49	.344086	5.98	.452462	7.67	49	.365306	5.82	.479890	7.57
50	.344445	5.97	.452922	7.67	50	.365655	5.80	.480344	7.57
51	9.344803	5.97	9.453382	7.67	51	9.366003	5.82	9.480798	7.57
52	.345161	5.97	.453842	7.67	52	.366352	5.80	.481252	7.55
53	.345519	5.97	.454302	7.67	53	.366700	5.80	.481705	7.57
54	.345877	5.97	.454762	7.65	54	.367048	5.80	.482159	7.57
55	.346235	5.95	.455221	7.67	55	.367396	5.80	.482613	7.55
56	.346592	5.97	.455681	7.65	56	.367744	5.78	.483066	7.57
57	.346950	5.95	.456140	7.67	57	.368091	5.80	.483520	7.55
58	.347307	5.95	.456600	7.65	58	.368439	5.78	.483973	7.55
59	.347664	5.95	.457059	7.65	59	.368786	5.78	.484426	7.55
60	9.348021	5.93	9.457518	7.65	60	9.369133	5.78	9.484879	7.55

40°

41°

	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.369133	5.78	9.484879	7.55	0	9.389681	5.62	9.511901	7.45
1	.369480	5.78	.485332	7.55	1	.390018	5.63	.512348	7.47
2	.369827	5.78	.485785	7.55	2	.390356	5.63	.512796	7.45
3	.370174	5.77	.486238	7.55	3	.390694	5.62	.513243	7.47
4	.370520	5.78	.486691	7.55	4	.391031	5.62	.513691	7.45
5	.370867	5.77	.487144	7.53	5	.391368	5.62	.514138	7.45
6	.371213	5.77	.487596	7.55	6	.391705	5.62	.514585	7.47
7	.371559	5.77	.488049	7.53	7	.392042	5.62	.515033	7.45
8	.371905	5.77	.488501	7.53	8	.392379	5.62	.515480	7.45
9	.372251	5.75	.488953	7.55	9	.392716	5.60	.515927	7.45
10	.372596	5.77	.489406	7.53	10	.393052	5.60	.516374	7.43
11	9.372942	5.75	9.489858	7.53	11	9.393388	5.60	9.516820	7.45
12	.373287	5.75	.490310	7.53	12	.393724	5.62	.517267	7.45
13	.373632	5.75	.490762	7.53	13	.394061	5.58	.517714	7.43
14	.373977	5.75	.491214	7.52	14	.394396	5.60	.518160	7.45
15	.374322	5.75	.491665	7.53	15	.394732	5.60	.518607	7.43
16	.374667	5.73	.492117	7.53	16	.395068	5.58	.519053	7.45
17	.375011	5.75	.492569	7.52	17	.395403	5.58	.519500	7.43
18	.375356	5.73	.493020	7.52	18	.395738	5.60	.519946	7.43
19	.375700	5.73	.493471	7.53	19	.396074	5.58	.520392	7.43
20	.376044	5.73	.493923	7.52	20	.396409	5.57	.520838	7.43
21	9.376388	5.73	9.494374	7.52	21	9.396743	5.58	9.521284	7.43
22	.376732	5.72	.494825	7.52	22	.397078	5.58	.521730	7.43
23	.377075	5.73	.495276	7.52	23	.397413	5.57	.522176	7.42
24	.377419	5.72	.495727	7.52	24	.397747	5.57	.522621	7.43
25	.377762	5.72	.496178	7.50	25	.398081	5.57	.523067	7.43
26	.378105	5.72	.496628	7.52	26	.398415	5.57	.523513	7.42
27	.378448	5.72	.497079	7.52	27	.398749	5.57	.523958	7.43
28	.378791	5.70	.497530	7.50	28	.399083	5.57	.524404	7.42
29	.379133	5.72	.497980	7.52	29	.399417	5.55	.524849	7.42
30	.379476	5.70	.498430	7.50	30	.399750	5.57	.525294	7.42
31	9.379818	5.72	9.498881	7.48	31	9.400084	5.55	9.525739	7.42
32	.380161	5.70	.499331	7.52	32	.400417	5.55	.526184	7.42
33	.380503	5.70	.499781	7.50	33	.400750	5.55	.526629	7.42
34	.380845	5.68	.500231	7.50	34	.401083	5.55	.527074	7.42
35	.381186	5.70	.500681	7.50	35	.401416	5.53	.527519	7.42
36	.381528	5.68	.501131	7.50	36	.401748	5.55	.527964	7.42
37	.381869	5.70	.501581	7.48	37	.402081	5.53	.528409	7.40
38	.382211	5.68	.502030	7.50	38	.402413	5.53	.528853	7.42
39	.382552	5.68	.502480	7.48	39	.402745	5.53	.529298	7.40
40	.382893	5.68	.502929	7.50	40	.403077	5.53	.529742	7.42
41	9.383234	5.67	9.503379	7.48	41	9.403409	5.53	9.530187	7.40
42	.383574	5.68	.503828	7.48	42	.403741	5.53	.530631	7.40
43	.383915	5.67	.504277	7.48	43	.404073	5.52	.531075	7.40
44	.384255	5.67	.504726	7.48	44	.404404	5.53	.531519	7.40
45	.384595	5.67	.505175	7.48	45	.404736	5.52	.531963	7.40
46	.384935	5.67	.505624	7.48	46	.405067	5.52	.532407	7.40
47	.385275	5.67	.506073	7.48	47	.405398	5.52	.532851	7.40
48	.385615	5.67	.506522	7.48	48	.405729	5.50	.533295	7.40
49	.385955	5.65	.506971	7.47	49	.406059	5.52	.533739	7.38
50	.386294	5.67	.507419	7.48	50	.406390	5.52	.534182	7.40
51	9.386634	5.65	9.507868	7.47	51	9.406721	5.50	9.534626	7.40
52	.386973	5.65	.508316	7.48	52	.407051	5.50	.535070	7.38
53	.387312	5.65	.508765	7.47	53	.407381	5.50	.535513	7.38
54	.387651	5.63	.509213	7.47	54	.407711	5.50	.535956	7.40
55	.387989	5.65	.509661	7.47	55	.408041	5.50	.536400	7.38
56	.388328	5.63	.510109	7.47	56	.408371	5.48	.536843	7.38
57	.388666	5.65	.510557	7.47	57	.408700	5.50	.537286	7.38
58	.389005	5.63	.511005	7.47	58	.409030	5.48	.537729	7.38
59	.389343	5.63	.511453	7.47	59	.409359	5.48	.538172	7.38
60	9.389681	5.62	9.511901	7.45	60	9.409688	5.48	9.538615	7.38

42°					43°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.409688	5.48	9.538615	7.38	0	9.429181	5.35	9.565053	7.32
1	.410017	5.48	.539058	7.37	1	.429502	5.33	.565492	7.30
2	.410346	5.48	.539500	7.38	2	.429822	5.33	.565930	7.32
3	.410675	5.48	.539943	7.38	3	.430142	5.35	.566369	7.30
4	.411004	5.47	.540386	7.37	4	.430463	5.33	.566807	7.30
5	.411332	5.47	.540828	7.38	5	.430783	5.33	.567245	7.30
6	.411660	5.48	.541271	7.37	6	.431103	5.32	.567683	7.30
7	.411989	5.47	.541713	7.37	7	.431422	5.33	.568121	7.30
8	.412317	5.45	.542155	7.37	8	.431742	5.33	.568559	7.30
9	.412644	5.47	.542597	7.38	9	.432062	5.32	.568997	7.30
10	.412972	5.47	.543040	7.37	10	.432381	5.32	.569435	7.30
11	9.413300	5.45	9.543482	7.37	11	9.432700	5.33	9.569873	7.30
12	.413627	5.47	.543924	7.37	12	.433020	5.32	.570311	7.28
13	.413955	5.45	.544366	7.35	13	.433339	5.30	.570748	7.30
14	.414282	5.45	.544807	7.37	14	.433657	5.32	.571186	7.30
15	.414609	5.45	.545249	7.37	15	.433976	5.32	.571624	7.28
16	.414936	5.45	.545691	7.35	16	.434295	5.30	.572061	7.28
17	.415263	5.43	.546132	7.37	17	.434613	5.32	.572498	7.30
18	.415589	5.45	.546574	7.35	18	.434932	5.30	.572936	7.28
19	.415916	5.43	.547015	7.37	19	.435250	5.30	.573373	7.28
20	.416242	5.43	.547457	7.35	20	.435568	5.30	.573810	7.28
21	9.416568	5.43	9.547898	7.35	21	9.435886	5.30	9.574247	7.30
22	.416894	5.43	.548339	7.37	22	.436204	5.28	.574685	7.28
23	.417220	5.43	.548781	7.35	23	.436521	5.30	.575122	7.27
24	.417546	5.42	.549222	7.35	24	.436839	5.28	.575558	7.30
25	.417871	5.43	.549663	7.35	25	.437156	5.28	.575995	7.28
26	.418197	5.42	.550104	7.33	26	.437473	5.30	.576432	7.28
27	.418522	5.43	.550544	7.35	27	.437791	5.27	.576869	7.23
28	.418848	5.42	.550985	7.35	28	.438107	5.28	.577306	7.27
29	.419173	5.42	.551426	7.35	29	.438424	5.28	.577742	7.28
30	.419498	5.40	.551867	7.33	30	.438741	5.28	.578179	7.27
31	9.419822	5.42	9.552307	7.35	31	9.439058	5.27	9.578615	7.28
32	.420147	5.40	.552748	7.33	32	.439374	5.27	.579052	7.27
33	.420471	5.42	.553188	7.35	33	.439690	5.28	.579488	7.27
34	.420796	5.46	.553629	7.33	34	.440007	5.27	.579924	7.28
35	.421120	5.40	.554069	7.33	35	.440323	5.27	.580361	7.27
36	.421444	5.40	.554509	7.33	36	.440639	5.25	.580797	7.27
37	.421768	5.40	.554949	7.33	37	.440954	5.27	.581233	7.27
38	.422092	5.40	.555389	7.33	38	.441270	5.25	.581669	7.27
39	.422416	5.38	.555829	7.33	39	.441586	5.27	.582105	7.27
40	.422739	5.40	.556269	7.33	40	.441901	5.25	.582541	7.27
41	9.423063	5.38	9.556709	7.33	41	9.442216	5.25	9.582977	7.27
42	.423386	5.38	.557149	7.33	42	.442531	5.25	.583413	7.25
43	.423709	5.38	.557589	7.32	43	.442846	5.25	.583848	7.27
44	.424032	5.38	.558028	7.33	44	.443161	5.25	.584284	7.27
45	.424355	5.37	.558468	7.32	45	.443476	5.23	.584720	7.25
46	.424677	5.38	.558907	7.33	46	.443790	5.25	.585155	7.27
47	.425000	5.37	.559347	7.32	47	.444105	5.23	.585591	7.25
48	.425322	5.38	.559786	7.33	48	.444419	5.23	.586026	7.27
49	.425645	5.37	.560226	7.32	49	.444733	5.23	.586462	7.25
50	.425967	5.37	.560665	7.32	50	.445047	5.23	.586897	7.25
51	9.426289	5.37	9.561104	7.32	51	9.445361	5.23	9.587332	7.25
52	.426611	5.37	.561543	7.32	52	.445675	5.23	.587767	7.27
53	.426933	5.35	.561982	7.32	53	.445989	5.22	.588203	7.25
54	.427254	5.37	.562421	7.32	54	.446302	5.23	.588638	7.25
55	.427576	5.35	.562860	7.32	55	.446616	5.22	.589073	7.25
56	.427897	5.35	.563299	7.32	56	.446929	5.22	.589508	7.23
57	.428218	5.35	.563738	7.30	57	.447242	5.22	.589942	7.25
58	.428539	5.35	.564176	7.32	58	.447555	5.22	.590377	7.25
59	.428860	5.35	.564615	7.30	59	.447868	5.22	.590812	7.25
60	9.429181	5.33	9.565053	7.32	60	9.448181	5.20	9.591247	7.23

44°					45°				
	Vers.	D. 1".	Ex. sec.	D. 1".		Vers.	D. 1".	Ex. sec.	D. 1".
0	9.448181	5.20	9.591247	7.23	0	9.466709	5.08	9.617224	7.20
1	.448493	5.22	.591681	7.25	1	.467014	5.08	.617656	7.18
2	.448806	5.20	.592116	7.25	2	.467319	5.08	.618087	7.18
3	.449118	5.22	.592551	7.23	3	.467624	5.07	.618518	7.18
4	.449431	5.20	.592985	7.23	4	.467928	5.08	.618949	7.18
5	.449743	5.20	.593419	7.25	5	.468233	5.07	.619380	7.18
6	.450055	5.18	.593854	7.23	6	.468537	5.07	.619811	7.18
7	.450366	5.20	.594288	7.23	7	.468841	5.07	.620242	7.18
8	.450678	5.20	.594722	7.23	8	.469145	5.07	.620673	7.18
9	.450990	5.18	.595156	7.25	9	.469449	5.07	.621104	7.18
10	.451301	5.18	.595591	7.23	10	.469753	5.07	.621535	7.18
11	9.451612	5.20	9.596025	7.23	11	9.470057	5.05	9.621966	7.17
12	.451924	5.18	.596459	7.23	12	.470360	5.07	.622396	7.18
13	.452235	5.18	.596893	7.22	13	.470664	5.05	.622827	7.18
14	.452546	5.17	.597326	7.23	14	.470967	5.05	.623258	7.17
15	.452856	5.17	.597760	7.23	15	.471270	5.05	.623688	7.18
16	.453167	5.18	.598194	7.23	16	.471573	5.05	.624119	7.17
17	.453478	5.17	.598628	7.22	17	.471876	5.05	.624549	7.18
18	.453788	5.17	.599061	7.23	18	.472179	5.05	.624980	7.17
19	.454098	5.17	.599495	7.22	19	.472482	5.03	.625410	7.18
20	.454408	5.17	.599928	7.23	20	.472784	5.05	.625841	7.17
21	9.454718	5.17	9.600362	7.22	21	9.473087	5.03	9.626271	7.17
22	.455028	5.17	.600795	7.23	22	.473389	5.03	.626701	7.17
23	.455338	5.17	.601229	7.22	23	.473691	5.03	.627131	7.17
24	.455648	5.15	.601662	7.22	24	.473993	5.03	.627561	7.17
25	.455957	5.17	.602095	7.22	25	.474295	5.03	.627991	7.17
26	.456267	5.15	.602528	7.23	26	.474597	5.03	.628421	7.17
27	.456576	5.15	.602962	7.22	27	.474899	5.02	.628851	7.17
28	.456885	5.15	.603395	7.22	28	.475200	5.03	.629281	7.17
29	.457194	5.15	.603828	7.22	29	.475502	5.02	.629711	7.17
30	.457503	5.13	.604261	7.22	30	.475803	5.02	.630141	7.17
31	9.457811	5.15	9.604694	7.20	31	9.476104	5.02	9.630571	7.17
32	.458120	5.15	.605126	7.22	32	.476405	5.02	.631001	7.15
33	.458429	5.13	.605559	7.22	33	.476706	5.02	.631430	7.17
34	.458737	5.13	.605992	7.22	34	.477007	5.02	.631860	7.17
35	.459045	5.13	.606425	7.20	35	.477308	5.00	.632290	7.15
36	.459353	5.13	.606857	7.22	36	.477608	5.02	.632719	7.17
37	.459661	5.13	.607290	7.20	37	.477909	5.00	.633149	7.15
38	.459969	5.13	.607722	7.22	38	.478209	5.00	.633578	7.17
39	.460277	5.12	.608155	7.20	39	.478509	5.00	.634008	7.15
40	.460584	5.13	.608587	7.22	40	.478809	5.00	.634437	7.15
41	9.460892	5.12	9.609020	7.20	41	9.479109	5.00	9.634866	7.17
42	.461199	5.12	.609452	7.20	42	.479409	5.00	.635296	7.15
43	.461506	5.12	.609884	7.20	43	.479709	5.00	.635725	7.15
44	.461813	5.12	.610316	7.22	44	.480009	4.98	.636154	7.15
45	.462120	5.12	.610749	7.20	45	.480308	5.00	.636583	7.15
46	.462427	5.12	.611181	7.20	46	.480608	4.98	.637012	7.15
47	.462734	5.10	.611613	7.20	47	.480907	4.98	.637441	7.15
48	.463040	5.12	.612045	7.20	48	.481206	4.98	.637870	7.15
49	.463347	5.10	.612477	7.18	49	.481505	4.98	.638299	7.15
50	.463653	5.10	.612908	7.20	50	.481804	4.98	.638728	7.15
51	9.463959	5.10	9.613340	7.20	51	9.482103	4.97	9.639157	7.15
52	.464265	5.10	.613772	7.20	52	.482401	4.98	.639586	7.15
53	.464571	5.10	.614204	7.18	53	.482700	4.97	.640015	7.13
54	.464877	5.10	.614635	7.20	54	.482998	4.97	.640443	7.15
55	.465183	5.08	.615067	7.20	55	.483296	4.98	.640872	7.15
56	.465488	5.10	.615499	7.18	56	.483595	4.97	.641301	7.13
57	.465794	5.08	.615930	7.20	57	.483893	4.97	.641729	7.15
58	.466099	5.08	.616362	7.18	58	.484191	4.95	.642158	7.13
59	.466404	5.08	.616793	7.18	59	.484488	4.97	.642586	7.15
60	9.466709	5.08	9.617224	7.20	60	9.484786	4.97	9.643015	7.13

46°					47°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.484786	4.97	9.643015	7.13	0	9.502429	4.85	9.668646	7.10
1	.485084	4.95	.643443	7.15	1	.502720	4.83	.669072	7.10
2	.485381	4.95	.643872	7.13	2	.503010	4.83	.669498	7.10
3	.485678	4.97	.644300	7.13	3	.503300	4.85	.669924	7.10
4	.485976	4.95	.644728	7.13	4	.503591	4.83	.670350	7.10
5	.486273	4.95	.645156	7.15	5	.503881	4.83	.670776	7.08
6	.486570	4.93	.645585	7.13	6	.504171	4.82	.671201	7.10
7	.486866	4.95	.646013	7.13	7	.504460	4.83	.671627	7.10
8	.487163	4.95	.646441	7.13	8	.504750	4.83	.672053	7.10
9	.487460	4.93	.646869	7.13	9	.505040	4.82	.672479	7.08
10	.487756	4.95	.647297	7.13	10	.505329	4.82	.672904	7.10
11	9.488053	4.93	9.647725	7.13	11	9.505618	4.83	9.673330	7.10
12	.488349	4.93	.648153	7.13	12	.505908	4.82	.673756	7.08
13	.488645	4.93	.648581	7.13	13	.506197	4.82	.674181	7.10
14	.488941	4.93	.649009	7.12	14	.506486	4.82	.674607	7.08
15	.489237	4.93	.649436	7.13	15	.506775	4.80	.675032	7.10
16	.489533	4.92	.649864	7.13	16	.507063	4.82	.675458	7.08
17	.489828	4.93	.650292	7.13	17	.507352	4.80	.675883	7.10
18	.490124	4.92	.650720	7.12	18	.507640	4.82	.676309	7.08
19	.490419	4.92	.651147	7.13	19	.507929	4.80	.676734	7.08
20	.490714	4.93	.651575	7.12	20	.508217	4.80	.677159	7.08
21	9.491010	4.92	9.652002	7.13	21	9.508505	4.80	9.677584	7.10
22	.491305	4.92	.652430	7.12	22	.508793	4.80	.678010	7.08
23	.491600	4.90	.652857	7.13	23	.509081	4.80	.678435	7.08
24	.491894	4.92	.653285	7.12	24	.509369	4.80	.678860	7.08
25	.492189	4.92	.653712	7.13	25	.509657	4.80	.679285	7.08
26	.492484	4.90	.654140	7.12	26	.509945	4.78	.679710	7.10
27	.492778	4.90	.654567	7.12	27	.510232	4.80	.680136	7.08
28	.493072	4.92	.654994	7.12	28	.510520	4.78	.680561	7.08
29	.493367	4.90	.655421	7.13	29	.510807	4.78	.680986	7.08
30	.493661	4.90	.655849	7.12	30	.511094	4.78	.681411	7.08
31	9.493955	4.90	9.656276	7.12	31	9.511381	4.78	9.681836	7.07
32	.494249	4.88	.656703	7.12	32	.511668	4.78	.682260	7.08
33	.494542	4.90	.657130	7.12	33	.511955	4.77	.682685	7.08
34	.494836	4.90	.657557	7.12	34	.512241	4.78	.683110	7.08
35	.495130	4.88	.657984	7.12	35	.512528	4.78	.683535	7.08
36	.495423	4.88	.658411	7.12	36	.512815	4.77	.683960	7.08
37	.495716	4.88	.658838	7.12	37	.513101	4.77	.684385	7.07
38	.496009	4.88	.659265	7.10	38	.513387	4.77	.684809	7.08
39	.496302	4.88	.659691	7.12	39	.513673	4.77	.685234	7.08
40	.496595	4.88	.660118	7.12	40	.513959	4.77	.685659	7.07
41	9.496888	4.88	9.660545	7.12	41	9.514245	4.77	9.686083	7.08
42	.497181	4.87	.660972	7.10	42	.514531	4.77	.686508	7.08
43	.497473	4.88	.661398	7.12	43	.514817	4.75	.686933	7.07
44	.497766	4.87	.661825	7.12	44	.515102	4.77	.687357	7.08
45	.498058	4.87	.662252	7.10	45	.515388	4.75	.687782	7.07
46	.498350	4.88	.662678	7.12	46	.515673	4.77	.688206	7.08
47	.498643	4.87	.663105	7.10	47	.515959	4.75	.688631	7.07
48	.498935	4.85	.663531	7.12	48	.516244	4.75	.689055	7.07
49	.499226	4.87	.663958	7.10	49	.516529	4.75	.689479	7.08
50	.499518	4.87	.664384	7.10	50	.516814	4.73	.689904	7.07
51	9.499810	4.85	9.664810	7.12	51	9.517098	4.75	9.690328	7.07
52	.500101	4.87	.665237	7.10	52	.517383	4.75	.690752	7.08
53	.500393	4.85	.665663	7.10	53	.517668	4.73	.691177	7.07
54	.500684	4.85	.666089	7.10	54	.517952	4.73	.691601	7.07
55	.500975	4.85	.666515	7.12	55	.518236	4.75	.692025	7.07
56	.501266	4.85	.666942	7.10	56	.518521	4.73	.692449	7.07
57	.501557	4.85	.667368	7.10	57	.518805	4.73	.692873	7.08
58	.501848	4.85	.667794	7.10	58	.519089	4.73	.693298	7.07
59	.502139	4.83	.668220	7.10	59	.519373	4.73	.693722	7.07
60	9.502429	4.85	9.668646	7.10	60	9.519657	4.72	9.694146	7.07

48°

49°

'	Vers.	D. 1'.	Ex. sec.	D. 1'.	'	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.519657	4.72	9.694146	7.07	0	9.536484	4.62	9.719541	7.05
1	.519940	4.73	.694570	7.07	1	.536761	4.62	.719964	7.03
2	.520224	4.72	.694994	7.07	2	.537038	4.62	.720386	7.05
3	.520507	4.73	.695418	7.07	3	.537315	4.62	.720809	7.03
4	.520791	4.72	.695842	7.07	4	.537592	4.62	.721231	7.03
5	.521074	4.72	.696266	7.05	5	.537869	4.60	.721653	7.05
6	.521357	4.72	.696689	7.07	6	.538145	4.62	.722076	7.03
7	.521640	4.72	.697113	7.07	7	.538422	4.60	.722498	7.05
8	.521923	4.72	.697537	7.07	8	.538698	4.60	.722921	7.03
9	.522206	4.70	.697961	7.07	9	.538974	4.62	.723343	7.03
10	.522488	4.72	.698385	7.07	10	.539251	4.60	.723765	7.05
11	9.522771	4.72	9.698809	7.05	11	9.539527	4.60	9.724188	7.03
12	.523054	4.70	.699232	7.07	12	.539803	4.60	.724610	7.03
13	.523336	4.70	.699656	7.07	13	.540079	4.58	.725032	7.03
14	.523618	4.70	.700080	7.05	14	.540354	4.60	.725454	7.05
15	.523900	4.70	.700503	7.07	15	.540630	4.60	.725877	7.03
16	.524182	4.70	.700927	7.05	16	.540906	4.58	.726299	7.03
17	.524464	4.70	.701350	7.07	17	.541181	4.58	.726721	7.03
18	.524746	4.70	.701774	7.07	18	.541456	4.60	.727143	7.03
19	.525028	4.68	.702198	7.05	19	.541732	4.58	.727565	7.05
20	.525309	4.70	.702621	7.07	20	.542007	4.58	.727988	7.03
21	9.525591	4.68	9.703045	7.05	21	9.542282	4.58	9.728410	7.03
22	.525872	4.68	.703468	7.05	22	.542557	4.58	.728832	7.03
23	.526153	4.70	.703891	7.07	23	.542832	4.57	.729254	7.03
24	.526435	4.68	.704315	7.05	24	.543106	4.58	.729676	7.03
25	.526716	4.68	.704738	7.07	25	.543381	4.57	.730098	7.03
26	.526997	4.67	.705162	7.05	26	.543655	4.58	.730520	7.03
27	.527277	4.68	.705585	7.05	27	.543930	4.57	.730942	7.03
28	.527558	4.68	.706008	7.05	28	.544204	4.57	.731364	7.03
29	.527839	4.67	.706431	7.07	29	.544478	4.57	.731786	7.03
30	.528119	4.68	.706855	7.05	30	.544752	4.57	.732208	7.03
31	9.528400	4.67	9.707278	7.05	31	9.545026	4.57	9.732630	7.03
32	.528680	4.67	.707701	7.05	32	.545300	4.57	.733052	7.03
33	.528960	4.67	.708124	7.05	33	.545574	4.57	.733474	7.03
34	.529240	4.67	.708547	7.07	34	.545848	4.55	.733896	7.02
35	.529520	4.67	.708971	7.05	35	.546121	4.57	.734317	7.03
36	.529800	4.67	.709394	7.05	36	.546395	4.55	.734739	7.03
37	.530080	4.65	.709817	7.05	37	.546668	4.55	.735161	7.03
38	.530359	4.67	.710240	7.05	38	.546941	4.55	.735583	7.03
39	.530639	4.65	.710663	7.05	39	.547214	4.55	.736005	7.03
40	.530918	4.67	.711086	7.05	40	.547487	4.55	.736427	7.02
41	9.531198	4.65	9.711509	7.05	41	9.547760	4.55	9.736848	7.03
42	.531477	4.65	.711932	7.05	42	.548033	4.55	.737270	7.03
43	.531756	4.65	.712355	7.05	43	.548306	4.55	.737692	7.03
44	.532035	4.65	.712778	7.03	44	.548579	4.53	.738114	7.02
45	.532314	4.63	.713200	7.05	45	.548851	4.55	.738535	7.03
46	.532592	4.65	.713623	7.05	46	.549124	4.53	.738957	7.03
47	.532871	4.65	.714046	7.05	47	.549396	4.53	.739379	7.02
48	.533150	4.63	.714469	7.05	48	.549668	4.53	.739800	7.03
49	.533428	4.63	.714892	7.05	49	.549940	4.53	.740222	7.03
50	.533706	4.65	.715315	7.03	50	.550212	4.53	.740644	7.02
51	9.533985	4.63	9.715737	7.05	51	9.550484	4.53	9.741065	7.03
52	.534263	4.63	.716160	7.05	52	.550756	4.53	.741487	7.02
53	.534541	4.63	.716583	7.03	53	.551028	4.52	.741908	7.03
54	.534819	4.63	.717005	7.05	54	.551299	4.53	.742330	7.02
55	.535097	4.62	.717428	7.05	55	.551571	4.52	.742751	7.03
56	.535374	4.63	.717851	7.03	56	.551842	4.52	.743173	7.03
57	.535652	4.62	.718273	7.05	57	.552113	4.52	.743595	7.02
58	.535929	4.63	.718696	7.03	58	.552384	4.53	.744016	7.03
59	.536207	4.62	.719118	7.05	59	.552656	4.52	.744438	7.02
60	9.536484	4.62	9.719541	7.05	60	9.552927	4.50	9.744859	7.02

50°					51°				
	Vers.	D. 1".	Ex. sec.	D. 1"		Vers.	D. 1".	Ex. sec.	D. 1".
0	9.532927	4.50	9.744859	7.02	0	9.563909	4.42	9.770127	7.03
1	.553197	4.51	.745280	7.03	1	.569264	4.40	.770548	7.02
2	.553408	4.52	.745702	7.02	2	.569528	4.42	.770969	7.00
3	.553739	4.50	.746123	7.03	3	.569793	4.40	.771389	7.02
4	.554009	4.52	.746545	7.02	4	.570057	4.42	.771810	7.03
5	.554280	4.50	.746966	7.03	5	.570322	4.40	.772231	7.03
6	.554550	4.50	.747388	7.02	6	.570586	4.40	.772652	7.02
7	.554820	4.52	.747809	7.02	7	.570850	4.40	.773073	7.02
8	.555091	4.50	.748230	7.03	8	.571114	4.40	.773494	7.00
9	.555361	4.50	.748652	7.02	9	.571378	4.40	.773914	7.02
10	.555631	4.48	.749073	7.02	10	.571642	4.40	.774335	7.02
11	9.555900	4.50	9.749494	7.03	11	9.571906	4.40	9.774756	7.02
12	.556170	4.50	.749916	7.02	12	.572170	4.40	.775177	7.02
13	.556440	4.48	.750337	7.02	13	.572434	4.38	.775598	7.00
14	.556709	4.50	.750758	7.03	14	.572697	4.38	.776018	7.02
15	.556979	4.48	.751180	7.02	15	.572960	4.40	.776439	7.02
16	.557248	4.48	.751601	7.02	16	.573224	4.38	.776860	7.02
17	.557517	4.48	.752022	7.02	17	.573487	4.38	.777281	7.02
18	.557786	4.48	.752443	7.03	18	.573750	4.38	.777702	7.00
19	.558055	4.48	.752865	7.02	19	.574013	4.38	.778123	7.02
20	.558324	4.48	.753286	7.02	20	.574276	4.38	.778543	7.02
21	9.558593	4.48	9.753707	7.02	21	9.574539	4.38	9.778964	7.02
22	.558862	4.48	.754128	7.02	22	.574802	4.37	.779385	7.00
23	.559131	4.47	.754549	7.03	23	.575064	4.38	.779805	7.02
24	.559399	4.47	.754971	7.02	24	.575327	4.37	.780226	7.02
25	.559667	4.48	.755392	7.02	25	.575589	4.38	.780647	7.02
26	.559936	4.47	.755813	7.02	26	.575852	4.37	.781068	7.00
27	.560204	4.47	.756234	7.02	27	.576114	4.37	.781488	7.02
28	.560472	4.47	.756655	7.02	28	.576376	4.37	.781909	7.02
29	.560740	4.47	.757076	7.03	29	.576638	4.37	.782330	7.02
30	.561008	4.47	.757498	7.02	30	.576900	4.37	.782751	7.00
31	9.561276	4.47	9.757919	7.02	31	9.577162	4.37	9.783171	7.02
32	.561544	4.45	.758340	7.02	32	.577424	4.35	.783592	7.02
33	.561811	4.47	.758761	7.02	33	.577685	4.37	.784013	7.00
34	.562079	4.45	.759182	7.03	34	.577947	4.35	.784433	7.02
35	.562346	4.45	.759603	7.02	35	.578208	4.37	.784854	7.02
36	.562613	4.47	.760024	7.02	36	.578470	4.35	.785275	7.02
37	.562881	4.45	.760445	7.02	37	.578731	4.35	.785696	7.00
38	.563148	4.45	.760866	7.02	38	.578992	4.35	.786116	7.02
39	.563415	4.45	.761287	7.02	39	.579253	4.35	.786537	7.02
40	.563682	4.43	.761708	7.02	40	.579514	4.35	.786958	7.00
41	9.563948	4.45	9.762129	7.02	41	9.579775	4.35	9.787378	7.02
42	.564215	4.45	.762550	7.02	42	.580036	4.35	.787799	7.02
43	.564482	4.43	.762971	7.02	43	.580297	4.33	.788220	7.02
44	.564748	4.45	.763392	7.02	44	.580557	4.35	.788641	7.00
45	.565015	4.43	.763813	7.02	45	.580818	4.33	.789061	7.02
46	.565281	4.43	.764234	7.02	46	.581078	4.35	.789482	7.02
47	.565547	4.43	.764655	7.02	47	.581339	4.33	.789903	7.00
48	.565813	4.43	.765076	7.02	48	.581599	4.33	.790323	7.02
49	.566079	4.43	.765497	7.02	49	.581859	4.33	.790744	7.02
50	.566345	4.43	.765918	7.02	50	.582119	4.33	.791165	7.02
51	9.566611	4.43	9.766339	7.02	51	9.582379	4.33	9.791586	7.00
52	.566877	4.42	.766760	7.02	52	.582639	4.32	.792006	7.02
53	.567142	4.43	.767181	7.02	53	.582898	4.33	.792427	7.02
54	.567408	4.42	.767602	7.00	54	.583158	4.33	.792848	7.00
55	.567673	4.42	.768022	7.02	55	.583418	4.32	.793268	7.02
56	.567938	4.43	.768443	7.02	56	.583677	4.32	.793689	7.02
57	.568204	4.42	.768864	7.02	57	.583936	4.33	.794110	7.02
58	.568469	4.42	.769285	7.02	58	.584196	4.32	.794531	7.00
59	.568734	4.42	.769706	7.02	59	.584455	4.32	.794951	7.02
60	9.568999	4.42	9.770127	7.02	60	9.584714	4.32	9.795372	7.02

52°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.584714	4.32	9.795372	7.02
1	.584973	4.32	.795793	7.00
2	.585232	4.32	.796213	7.02
3	.585491	4.30	.796634	7.02
4	.585749	4.32	.797055	7.02
5	.586008	4.30	.797476	7.00
6	.586266	4.32	.797896	7.02
7	.586525	4.30	.798317	7.02
8	.586783	4.30	.798738	7.00
9	.587041	4.30	.799158	7.02
10	.587299	4.30	.799579	7.02
11	9.587557	4.30	9.800000	7.02
12	.587815	4.30	.800421	7.00
13	.588073	4.30	.800841	7.02
14	.588331	4.28	.801262	7.02
15	.588588	4.28	.801683	7.02
16	.588846	4.28	.802104	7.00
17	.589103	4.30	.802524	7.02
18	.589361	4.28	.802945	7.02
19	.589618	4.28	.803366	7.02
20	.589875	4.28	.803787	7.00
21	9.590132	4.28	9.804207	7.02
22	.590389	4.28	.804628	7.02
23	.590646	4.28	.805049	7.02
24	.590903	4.28	.805470	7.02
25	.591160	4.27	.805891	7.00
26	.591416	4.28	.806311	7.02
27	.591673	4.27	.806732	7.02
28	.591929	4.27	.807153	7.02
29	.592185	4.28	.807574	7.02
30	.592442	4.27	.807995	7.00
31	9.592698	4.27	9.808415	7.02
32	.592954	4.27	.808836	7.02
33	.593210	4.27	.809257	7.02
34	.593466	4.25	.809678	7.02
35	.593721	4.27	.810099	7.02
36	.593977	4.27	.810520	7.00
37	.594233	4.25	.810940	7.02
38	.594488	4.25	.811361	7.02
39	.594743	4.27	.811782	7.02
40	.594999	4.25	.812203	7.02
41	9.595254	4.25	9.812624	7.02
42	.595509	4.25	.813045	7.02
43	.595764	4.25	.813466	7.00
44	.596019	4.25	.813886	7.02
45	.596274	4.23	.814307	7.02
46	.596528	4.25	.814728	7.02
47	.596783	4.25	.815149	7.02
48	.597038	4.23	.815570	7.02
49	.597292	4.23	.815991	7.02
50	.597546	4.25	.816412	7.02
51	9.597801	4.23	9.816833	7.02
52	.598055	4.23	.817254	7.02
53	.598309	4.23	.817675	7.02
54	.598563	4.23	.818096	7.02
55	.598817	4.23	.818517	7.02
56	.599071	4.22	.818938	7.02
57	.599324	4.23	.819359	7.02
58	.599578	4.22	.819780	7.02
59	.599831	4.23	.820201	7.02
60	9.600085	4.22	9.820622	7.02

53°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.600085	4.22	9.820622	7.02
1	.600338	4.22	.821043	7.02
2	.600591	4.23	.821464	7.02
3	.600845	4.22	.821885	7.02
4	.601098	4.22	.822306	7.02
5	.601351	4.20	.822727	7.02
6	.601608	4.22	.823148	7.02
7	.601856	4.22	.823569	7.02
8	.602109	4.22	.823990	7.02
9	.602362	4.20	.824411	7.03
10	.602614	4.20	.824833	7.02
11	9.602866	4.22	9.825254	7.02
12	.603119	4.20	.825675	7.02
13	.603371	4.20	.826096	7.02
14	.603623	4.20	.826517	7.02
15	.603875	4.20	.826938	7.02
16	.604127	4.20	.827360	7.03
17	.604379	4.20	.827781	7.02
18	.604631	4.20	.828202	7.02
19	.604883	4.18	.828623	7.03
20	.605134	4.20	.829044	7.03
21	9.605386	4.18	9.829466	7.02
22	.605637	4.18	.829887	7.02
23	.605888	4.20	.830308	7.02
24	.606140	4.18	.830729	7.03
25	.606391	4.18	.831151	7.02
26	.606642	4.18	.831572	7.02
27	.606893	4.18	.831993	7.03
28	.607144	4.17	.832415	7.02
29	.607394	4.18	.832836	7.02
30	.607645	4.18	.833257	7.03
31	9.607896	4.17	9.833679	7.02
32	.608146	4.18	.834100	7.03
33	.608397	4.17	.834522	7.02
34	.608647	4.17	.834943	7.02
35	.608897	4.17	.835364	7.03
36	.609147	4.17	.835786	7.02
37	.609397	4.17	.836207	7.03
38	.609647	4.17	.836629	7.02
39	.609897	4.17	.837050	7.03
40	.610147	4.17	.837472	7.02
41	9.610397	4.15	9.837898	7.03
42	.610646	4.17	.838315	7.02
43	.610896	4.15	.838736	7.03
44	.611145	4.15	.839158	7.02
45	.611394	4.17	.839579	7.03
46	.611644	4.15	.840001	7.02
47	.611893	4.15	.840423	7.03
48	.612142	4.15	.840844	7.03
49	.612391	4.15	.841266	7.02
50	.612640	4.13	.841687	7.03
51	9.612888	4.15	9.842109	7.03
52	.613137	4.15	.842531	7.03
53	.613386	4.13	.842953	7.02
54	.613634	4.15	.843374	7.03
55	.613883	4.13	.843796	7.03
56	.614131	4.13	.844218	7.02
57	.614379	4.13	.844639	7.03
58	.614627	4.15	.845061	7.03
59	.614876	4.13	.845483	7.03
60	9.615124	4.12	9.845905	7.03

54°					55°				
'	Vers.	D. 1'.	Ex. sec.	D. 1'.	'	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.615124	4.12	9.845905	7.03	0	9.629841	4.05	9.871250	7.05
1	.615371	4.13	.846337	7.03	1	.630084	4.03	.871673	7.05
2	.615619	4.13	.846749	7.02	2	.630326	4.05	.872096	7.05
3	.615867	4.13	.847170	7.03	3	.630569	4.03	.872519	7.05
4	.616115	4.12	.847592	7.03	4	.630811	4.05	.872942	7.07
5	.616362	4.13	.848014	7.03	5	.631054	4.03	.873366	7.05
6	.616610	4.12	.848436	7.03	6	.631296	4.03	.873789	7.05
7	.616857	4.12	.848858	7.03	7	.631538	4.03	.874212	7.07
8	.617104	4.12	.849280	7.03	8	.631780	4.03	.874636	7.05
9	.617351	4.12	.849702	7.03	9	.632022	4.03	.875059	7.05
10	.617598	4.12	.850124	7.03	10	.632264	4.02	.875482	7.07
11	9.617845	4.12	9.850546	7.03	11	9.632505	4.03	9.875906	7.05
12	.618092	4.12	.850968	7.03	12	.632747	4.03	.876329	7.05
13	.618339	4.12	.851390	7.03	13	.632989	4.02	.876752	7.07
14	.618586	4.12	.851812	7.03	14	.633230	4.03	.877176	7.05
15	.618833	4.10	.852234	7.03	15	.633472	4.02	.877599	7.07
16	.619079	4.12	.852656	7.03	16	.633713	4.02	.878023	7.05
17	.619326	4.10	.853078	7.03	17	.633954	4.03	.878446	7.07
18	.619572	4.10	.853500	7.05	18	.634196	4.02	.878870	7.07
19	.619818	4.12	.853923	7.03	19	.634437	4.02	.879294	7.05
20	.620065	4.10	.854345	7.03	20	.634678	4.02	.879717	7.07
21	9.620311	4.10	9.854767	7.03	21	9.634919	4.00	9.880141	7.07
22	.620557	4.10	.855189	7.05	22	.635159	4.02	.880565	7.05
23	.620803	4.08	.855612	7.03	23	.635400	4.02	.880988	7.07
24	.621048	4.10	.856034	7.03	24	.635641	4.00	.881412	7.07
25	.621294	4.10	.856456	7.03	25	.635881	4.02	.881836	7.07
26	.621540	4.10	.856878	7.05	26	.636122	4.00	.882260	7.05
27	.621786	4.08	.857301	7.03	27	.636362	4.02	.882683	7.07
28	.622031	4.08	.857723	7.03	28	.636603	4.00	.883107	7.07
29	.622276	4.10	.858145	7.05	29	.636843	4.00	.883531	7.07
30	.622522	4.08	.858568	7.03	30	.637083	4.00	.883955	7.07
31	9.622767	4.08	9.858990	7.05	31	9.637323	4.00	9.884379	7.07
32	.623012	4.08	.859413	7.03	32	.637563	4.00	.884803	7.07
33	.623257	4.08	.859835	7.05	33	.637803	4.00	.885227	7.07
34	.623502	4.08	.860258	7.03	34	.638043	4.00	.885651	7.07
35	.623747	4.08	.860680	7.05	35	.638283	3.98	.886075	7.07
36	.623992	4.08	.861103	7.03	36	.638522	4.00	.886499	7.07
37	.624237	4.07	.861525	7.05	37	.638762	3.98	.886923	7.07
38	.624481	4.08	.861948	7.03	38	.639001	4.00	.887347	7.08
39	.624726	4.07	.862370	7.05	39	.639241	3.98	.887772	7.07
40	.624970	4.08	.862793	7.03	40	.639480	3.98	.888196	7.07
41	9.625215	4.07	9.863215	7.05	41	9.639719	3.98	9.888620	7.07
42	.625459	4.07	.863638	7.05	42	.639958	3.98	.889044	7.08
43	.625703	4.07	.864061	7.03	43	.640197	3.98	.889469	7.07
44	.625947	4.07	.864483	7.05	44	.640436	3.98	.889893	7.07
45	.626191	4.07	.864906	7.05	45	.640675	3.98	.890317	7.08
46	.626435	4.07	.865329	7.05	46	.640914	3.98	.890742	7.07
47	.626679	4.07	.865752	7.03	47	.641153	3.97	.891166	7.08
48	.626923	4.05	.866174	7.05	48	.641391	3.98	.891591	7.07
49	.627166	4.07	.866597	7.05	49	.641630	3.97	.892015	7.08
50	.627410	4.07	.867020	7.05	50	.641868	3.98	.892440	7.07
51	9.627654	4.05	9.867443	7.05	51	9.642107	3.97	9.892864	7.08
52	.627897	4.05	.867866	7.05	52	.642345	3.97	.893289	7.08
53	.628140	4.07	.868289	7.05	53	.642583	3.98	.893714	7.07
54	.628384	4.05	.868712	7.05	54	.642822	3.97	.894138	7.08
55	.628627	4.05	.869135	7.05	55	.643060	3.97	.894563	7.08
56	.628870	4.05	.869558	7.05	56	.643298	3.95	.894988	7.07
57	.629113	4.05	.869981	7.05	57	.643535	3.97	.895412	7.08
58	.629356	4.03	.870404	7.05	58	.643773	3.97	.895837	7.08
59	.629598	4.05	.870827	7.05	59	.644011	3.97	.896262	7.08
60	9.629841	4.05	9.871250	7.05	60	9.644249	3.95	9.896687	7.08

56°

57°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.644249	3.95	9.896687	7.08
1	.644486	3.97	.897112	7.08
2	.644724	3.95	.897537	7.08
3	.644961	3.95	.897962	7.03
4	.645198	3.95	.898387	7.08
5	.645436	3.97	.898812	7.08
6	.645673	3.95	.899237	7.08
7	.645910	3.95	.899662	7.08
8	.646147	3.95	.900087	7.08
9	.646384	3.93	.900512	7.10
10	.646620	3.95	.900938	7.08
11	9.646857	3.95	9.901363	7.08
12	.647094	3.93	.901788	7.08
13	.647330	3.95	.902213	7.10
14	.647567	3.93	.902639	7.08
15	.647803	3.93	.903064	7.10
16	.648039	3.95	.903490	7.08
17	.648276	3.93	.903915	7.10
18	.648512	3.93	.904341	7.08
19	.648748	3.93	.904766	7.10
20	.648984	3.93	.905192	7.08
21	9.649220	3.93	9.905617	7.10
22	.649456	3.92	.906043	7.10
23	.649691	3.93	.906469	7.08
24	.649927	3.93	.906894	7.10
25	.650163	3.92	.907320	7.10
26	.650398	3.92	.907746	7.10
27	.650633	3.93	.908172	7.10
28	.650869	3.92	.908598	7.10
29	.651104	3.92	.909024	7.10
30	.651339	3.92	.909450	7.10
31	9.651574	3.92	9.909876	7.10
32	.651809	3.92	.910302	7.10
33	.652044	3.92	.910728	7.10
34	.652279	3.92	.911154	7.10
35	.652514	3.90	.911580	7.10
36	.652748	3.92	.912006	7.10
37	.652983	3.90	.912432	7.12
38	.653217	3.92	.912859	7.10
39	.653452	3.90	.913285	7.10
40	.653686	3.90	.913711	7.12
41	9.653920	3.92	9.914138	7.10
42	.654155	3.90	.914564	7.12
43	.654389	3.90	.914991	7.10
44	.654623	3.90	.915417	7.12
45	.654857	3.88	.915844	7.10
46	.655090	3.90	.916270	7.12
47	.655324	3.90	.916697	7.12
48	.655558	3.90	.917124	7.10
49	.655792	3.88	.917550	7.12
50	.656025	3.88	.917977	7.12
51	9.656258	3.90	9.918404	7.12
52	.656492	3.88	.918831	7.12
53	.656725	3.88	.919258	7.12
54	.656958	3.88	.919685	7.12
55	.657191	3.88	.920112	7.12
56	.657424	3.88	.920539	7.12
57	.657657	3.88	.920966	7.12
58	.657890	3.88	.921393	7.12
59	.658123	3.88	.921820	7.12
60	9.658356	3.87	9.922247	7.12

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.658356	3.87	9.922247	7.12
1	.658588	3.88	.922674	7.13
2	.658821	3.87	.923102	7.12
3	.659053	3.88	.923529	7.12
4	.659286	3.87	.923956	7.13
5	.659518	3.87	.924384	7.12
6	.659750	3.88	.924811	7.13
7	.659983	3.87	.925239	7.12
8	.660215	3.87	.925666	7.13
9	.660447	3.87	.926094	7.12
10	.660679	3.85	.926521	7.13
11	9.660910	3.87	9.926949	7.13
12	.661142	3.87	.927377	7.12
13	.661374	3.85	.927804	7.13
14	.661605	3.87	.928232	7.13
15	.661837	3.85	.928660	7.13
16	.662068	3.87	.929088	7.13
17	.662300	3.85	.929516	7.13
18	.662531	3.85	.929944	7.13
19	.662762	3.85	.930372	7.13
20	.662993	3.85	.930800	7.13
21	9.663224	3.85	9.931228	7.13
22	.663455	3.85	.931656	7.15
23	.663686	3.85	.932085	7.13
24	.663917	3.85	.932513	7.12
25	.664148	3.83	.932941	7.13
26	.664378	3.85	.933369	7.15
27	.664609	3.83	.933798	7.13
28	.664839	3.85	.934226	7.15
29	.665070	3.83	.934655	7.13
30	.665300	3.83	.935083	7.15
31	9.665530	3.83	9.935512	7.15
32	.665760	3.83	.935941	7.13
33	.665990	3.83	.936369	7.15
34	.666220	3.83	.936798	7.15
35	.666450	3.83	.937227	7.15
36	.666680	3.83	.937656	7.15
37	.666910	3.82	.938085	7.13
38	.667139	3.83	.938513	7.15
39	.667369	3.83	.938942	7.15
40	.667599	3.82	.939371	7.17
41	9.667828	3.82	9.939801	7.15
42	.668057	3.83	.940230	7.15
43	.668287	3.82	.940659	7.15
44	.668516	3.82	.941088	7.15
45	.668745	3.82	.941517	7.17
46	.668974	3.82	.941947	7.15
47	.669203	3.82	.942376	7.15
48	.669432	3.82	.942806	7.15
49	.669661	3.80	.943235	7.17
50	.669889	3.82	.943665	7.15
51	9.670118	3.82	9.944094	7.17
52	.670347	3.80	.944524	7.15
53	.670575	3.82	.944953	7.17
54	.670804	3.80	.945383	7.17
55	.671032	3.80	.945813	7.17
56	.671260	3.80	.946243	7.17
57	.671488	3.80	.946673	7.17
58	.671716	3.82	.947103	7.17
59	.671945	3.78	.947533	7.17
60	9.672172	3.80	9.947963	7.17

58°					59°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.672172	3.80	9.947963	7.17	0	9.685708	3.72	9.973868	7.23
1	.672400	3.80	.948393	7.17	1	.685931	3.72	.974302	7.23
2	.672628	3.80	.948823	7.17	2	.686154	3.72	.974736	7.22
3	.672856	3.78	.949253	7.17	3	.686377	3.72	.975169	7.23
4	.673083	3.80	.949683	7.18	4	.686600	3.72	.975603	7.23
5	.673311	3.78	.950114	7.17	5	.686823	3.72	.976037	7.23
6	.673538	3.80	.950544	7.18	6	.687046	3.72	.976471	7.23
7	.673766	3.78	.950975	7.17	7	.687269	3.72	.976905	7.23
8	.673993	3.78	.951405	7.18	8	.687492	3.70	.977339	7.23
9	.674220	3.80	.951836	7.17	9	.687714	3.72	.977773	7.23
10	.674448	3.78	.952266	7.18	10	.687937	3.70	.978207	7.23
11	9.674675	3.78	9.952697	7.18	11	9.688159	3.72	9.978641	7.23
12	.674902	3.78	.953128	7.17	12	.688382	3.70	.979075	7.25
13	.675129	3.78	.953558	7.18	13	.688604	3.70	.979510	7.23
14	.675356	3.77	.953989	7.18	14	.688826	3.70	.979944	7.25
15	.675582	3.78	.954420	7.18	15	.689048	3.72	.980379	7.23
16	.675809	3.78	.954851	7.18	16	.689271	3.70	.980813	7.25
17	.676036	3.77	.955282	7.18	17	.689493	3.70	.981248	7.23
18	.676262	3.78	.955713	7.18	18	.689715	3.70	.981682	7.25
19	.676489	3.77	.956144	7.18	19	.689937	3.68	.982117	7.25
20	.676715	3.77	.956575	7.18	20	.690158	3.70	.982552	7.25
21	9.676941	3.78	9.957006	7.20	21	9.690380	3.70	9.982987	7.25
22	.677168	3.77	.957438	7.18	22	.690602	3.68	.983422	7.25
23	.677394	3.77	.957869	7.18	23	.690823	3.70	.983857	7.25
24	.677620	3.77	.958300	7.20	24	.691045	3.68	.984292	7.25
25	.677846	3.77	.958732	7.18	25	.691266	3.70	.984727	7.25
26	.678072	3.77	.959163	7.20	26	.691488	3.68	.985162	7.25
27	.678298	3.75	.959595	7.18	27	.691709	3.68	.985597	7.27
28	.678523	3.77	.960026	7.20	28	.691930	3.68	.986033	7.25
29	.678749	3.77	.960458	7.20	29	.692151	3.68	.986468	7.27
30	.678975	3.75	.960890	7.18	30	.692372	3.68	.986904	7.25
31	9.679200	3.77	9.961321	7.20	31	9.692593	3.68	9.987339	7.27
32	.679426	3.75	.961753	7.20	32	.692814	3.68	.987775	7.25
33	.679651	3.75	.962185	7.20	33	.693035	3.68	.988210	7.27
34	.679876	3.77	.962617	7.20	34	.693256	3.68	.988646	7.27
35	.680102	3.75	.963049	7.20	35	.693477	3.67	.989082	7.27
36	.680327	3.75	.963481	7.20	36	.693697	3.68	.989518	7.27
37	.680552	3.75	.963913	7.20	37	.693918	3.67	.989954	7.27
38	.680777	3.75	.964345	7.22	38	.694138	3.68	.990390	7.27
39	.681002	3.75	.964778	7.20	39	.694359	3.67	.990826	7.27
40	.681227	3.73	.965210	7.20	40	.694579	3.67	.991262	7.27
41	9.681451	3.75	9.965642	7.22	41	9.694799	3.67	9.991698	7.27
42	.681676	3.75	.966075	7.20	42	.695019	3.68	.992134	7.28
43	.681901	3.73	.966507	7.22	43	.695240	3.67	.992571	7.27
44	.682125	3.75	.966940	7.20	44	.695460	3.67	.993007	7.28
45	.682350	3.73	.967372	7.22	45	.695680	3.65	.993444	7.27
46	.682574	3.73	.967805	7.22	46	.695899	3.67	.993880	7.28
47	.682798	3.75	.968238	7.20	47	.696119	3.67	.994317	7.28
48	.683023	3.73	.968670	7.22	48	.696339	3.67	.994754	7.28
49	.683247	3.73	.969103	7.22	49	.696559	3.65	.995191	7.27
50	.683471	3.73	.969536	7.22	50	.696778	3.67	.995627	7.28
51	9.683695	3.73	9.969969	7.22	51	9.696998	3.65	9.996064	7.28
52	.683919	3.73	.970402	7.22	52	.697217	3.67	.996501	7.28
53	.684143	3.73	.970835	7.22	53	.697437	3.65	.996938	7.30
54	.684367	3.72	.971268	7.22	54	.697656	3.65	.997376	7.28
55	.684590	3.73	.971701	7.23	55	.697875	3.65	.997813	7.28
56	.684814	3.72	.972135	7.22	56	.698094	3.65	.998250	7.28
57	.685037	3.73	.972568	7.22	57	.698313	3.65	.998687	7.30
58	.685261	3.72	.973001	7.23	58	.698532	3.65	.999125	7.28
59	.685484	3.73	.973435	7.22	59	.698751	3.65	9.999562	7.30
60	9.685708	3.72	9.973868	7.23	60	9.698970	3.63	10.000000	7.30

60°

61°

	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.698970	3.65	10.000000	7.30	0	9.711968	3.57	10.026397	7.37
1	.699189	3.63	.000438	7.28	1	.712182	3.58	.026839	7.37
2	.699407	3.65	.000875	7.30	2	.712397	3.57	.027281	7.38
3	.699626	3.65	.001313	7.30	3	.712611	3.57	.027724	7.38
4	.699845	3.63	.001751	7.30	4	.712825	3.57	.028167	7.37
5	.700063	3.65	.002189	7.30	5	.713039	3.57	.028609	7.38
6	.700282	3.63	.002627	7.30	6	.713253	3.57	.029052	7.38
7	.700500	3.63	.003065	7.30	7	.713467	3.57	.029495	7.38
8	.700718	3.63	.003503	7.32	8	.713681	3.57	.029938	7.38
9	.700936	3.63	.003942	7.30	9	.713895	3.57	.030381	7.40
10	.701154	3.63	.004380	7.30	10	.714109	3.57	.030825	7.38
11	9.701372	3.63	10.004818	7.32	11	9.714323	3.55	10.031268	7.38
12	.701590	3.63	.005257	7.30	12	.714536	3.57	.031711	7.40
13	.701808	3.63	.005695	7.32	13	.714750	3.55	.032155	7.38
14	.702026	3.63	.006134	7.32	14	.714963	3.57	.032598	7.40
15	.702244	3.63	.006573	7.32	15	.715177	3.55	.033042	7.40
16	.702462	3.62	.007012	7.30	16	.715390	3.55	.033486	7.38
17	.702679	3.63	.007450	7.32	17	.715603	3.57	.033929	7.40
18	.702897	3.62	.007889	7.32	18	.715817	3.55	.034373	7.40
19	.703114	3.63	.008328	7.32	19	.716030	3.55	.034817	7.40
20	.703332	3.62	.008767	7.33	20	.716243	3.55	.035261	7.40
21	9.703549	3.62	10.009207	7.32	21	9.716456	3.55	10.035705	7.42
22	.703766	3.62	.009646	7.32	22	.716669	3.55	.036150	7.40
23	.703983	3.62	.010085	7.33	23	.716882	3.55	.036594	7.40
24	.704200	3.62	.010525	7.32	24	.717095	3.53	.037038	7.42
25	.704417	3.62	.010964	7.33	25	.717307	3.55	.037483	7.42
26	.704634	3.62	.011404	7.32	26	.717520	3.53	.037928	7.40
27	.704851	3.62	.011843	7.33	27	.717732	3.55	.038372	7.42
28	.705068	3.62	.012283	7.33	28	.717945	3.53	.038817	7.42
29	.705285	3.60	.012723	7.33	29	.718157	3.55	.039262	7.42
30	.705501	3.62	.013163	7.33	30	.718370	3.53	.039707	7.42
31	9.705718	3.62	10.013603	7.33	31	9.718582	3.53	10.040152	7.42
32	.705935	3.60	.014043	7.33	32	.718794	3.55	.040597	7.42
33	.706151	3.60	.014483	7.33	33	.719007	3.53	.041042	7.43
34	.706367	3.62	.014923	7.33	34	.719219	3.53	.041488	7.42
35	.706584	3.60	.015363	7.35	35	.719431	3.53	.041933	7.43
36	.706800	3.60	.015804	7.33	36	.719643	3.53	.042379	7.42
37	.707016	3.60	.016244	7.33	37	.719855	3.52	.042824	7.43
38	.707232	3.60	.016684	7.33	38	.720066	3.53	.043270	7.43
39	.707448	3.60	.017125	7.35	39	.720278	3.53	.043716	7.43
40	.707664	3.60	.017566	7.35	40	.720490	3.52	.044162	7.43
41	9.707880	3.60	10.018007	7.33	41	9.720701	3.53	10.044608	7.43
42	.708096	3.58	.018447	7.35	42	.720913	3.52	.045054	7.43
43	.708311	3.60	.018888	7.35	43	.721124	3.53	.045500	7.43
44	.708527	3.60	.019329	7.35	44	.721336	3.52	.045946	7.45
45	.708743	3.58	.019770	7.37	45	.721547	3.52	.046393	7.43
46	.708958	3.60	.020212	7.35	46	.721758	3.53	.046839	7.45
47	.709174	3.58	.020653	7.35	47	.721970	3.52	.047286	7.43
48	.709389	3.58	.021094	7.35	48	.722181	3.52	.047732	7.45
49	.709604	3.58	.021535	7.37	49	.722392	3.52	.048179	7.45
50	.709819	3.58	.021977	7.37	50	.722603	3.52	.048626	7.45
51	9.710035	3.58	10.022419	7.35	51	9.722814	3.50	10.049073	7.45
52	.710250	3.58	.022860	7.37	52	.723024	3.52	.049520	7.45
53	.710465	3.58	.023302	7.37	53	.723235	3.52	.049967	7.45
54	.710680	3.58	.023744	7.37	54	.723446	3.52	.050414	7.45
55	.710895	3.57	.024186	7.37	55	.723657	3.50	.050861	7.47
56	.711109	3.58	.024628	7.37	56	.723867	3.52	.051309	7.45
57	.711324	3.58	.025070	7.37	57	.724078	3.50	.051756	7.47
58	.711539	3.57	.025512	7.37	58	.724288	3.50	.052204	7.47
59	.711753	3.58	.025954	7.38	59	.724498	3.52	.052652	7.45
60	9.711968	3.57	10.026397	7.37	60	9.724709	3.50	10.053099	7.47

62°					63°				
•	Vers.	D. 1".	Ex. sec.	D. 1".	•	Vers.	D. 1".	Ex. sec.	D. 1".
0	9.724709	3.50	10.053099	7.47	0	9.737200	3.43	10.080153	7.58
1	.724919	3.50	.053547	7.47	1	.737406	3.43	.080608	7.57
2	.725129	3.50	.053996	7.47	2	.737612	3.43	.081062	7.57
3	.725339	3.50	.054443	7.48	3	.737818	3.43	.081516	7.58
4	.725549	3.50	.054892	7.47	4	.738024	3.43	.081971	7.57
5	.725759	3.50	.055340	7.47	5	.738230	3.43	.082425	7.58
6	.725969	3.50	.055788	7.48	6	.738436	3.43	.082880	7.58
7	.726179	3.48	.056237	7.47	7	.738642	3.42	.083335	7.58
8	.726388	3.50	.056685	7.48	8	.738847	3.43	.083790	7.58
9	.726598	3.50	.057134	7.48	9	.739053	3.42	.084245	7.58
10	.726808	3.48	.057583	7.48	10	.739258	3.43	.084700	7.58
11	9.727017	3.50	10.058032	7.48	11	9.739464	3.42	10.085155	7.60
12	.727227	3.48	.058481	7.48	12	.739669	3.43	.085611	7.58
13	.727436	3.48	.058930	7.48	13	.739875	3.42	.086066	7.60
14	.727645	3.50	.059379	7.48	14	.740080	3.42	.086522	7.58
15	.727855	3.48	.059828	7.50	15	.740285	3.42	.086977	7.60
16	.728064	3.48	.060278	7.48	16	.740490	3.42	.087433	7.60
17	.728273	3.48	.060727	7.50	17	.740695	3.42	.087889	7.60
18	.728482	3.48	.061177	7.48	18	.740900	3.42	.088345	7.60
19	.728691	3.48	.061626	7.50	19	.741105	3.42	.088801	7.62
20	.728900	3.48	.062076	7.50	20	.741310	3.42	.089258	7.60
21	9.729109	3.47	10.062526	7.50	21	9.741515	3.40	10.089714	7.62
22	.729317	3.48	.062976	7.50	22	.741719	3.42	.090171	7.60
23	.729526	3.48	.063426	7.50	23	.741924	3.42	.090627	7.62
24	.729735	3.47	.063876	7.52	24	.742129	3.40	.091084	7.62
25	.729943	3.48	.064327	7.50	25	.742333	3.42	.091541	7.62
26	.730152	3.47	.064777	7.50	26	.742538	3.40	.091998	7.62
27	.730360	3.48	.065227	7.52	27	.742742	3.40	.092455	7.62
28	.730569	3.47	.065678	7.52	28	.742946	3.40	.092912	7.63
29	.730777	3.47	.066129	7.52	29	.743150	3.42	.093370	7.62
30	.730985	3.47	.066580	7.50	30	.743355	3.40	.093827	7.63
31	9.731193	3.47	10.067030	7.53	31	9.743559	3.40	10.094285	7.63
32	.731401	3.47	.067482	7.52	32	.743762	3.40	.094743	7.62
33	.731609	3.47	.067933	7.52	33	.743967	3.40	.095200	7.63
34	.731817	3.47	.068384	7.52	34	.744171	3.40	.095658	7.63
35	.732025	3.47	.068835	7.53	35	.744375	3.38	.096116	7.65
36	.732233	3.47	.069287	7.52	36	.744578	3.40	.096575	7.63
37	.732441	3.45	.069738	7.53	37	.744782	3.40	.097033	7.63
38	.732648	3.47	.070190	7.53	38	.744986	3.38	.097491	7.65
39	.732856	3.47	.070642	7.52	39	.745189	3.40	.097950	7.63
40	.733064	3.45	.071093	7.53	40	.745393	3.38	.098408	7.65
41	9.733271	3.45	10.071545	7.55	41	9.745596	3.40	10.098867	7.65
42	.733478	3.47	.071998	7.53	42	.745800	3.38	.099326	7.65
43	.733686	3.45	.072450	7.53	43	.746003	3.38	.099785	7.65
44	.733893	3.45	.072902	7.53	44	.746206	3.38	.100244	7.67
45	.734100	3.45	.073354	7.55	45	.746409	3.40	.100704	7.65
46	.734307	3.47	.073807	7.55	46	.746613	3.38	.101163	7.67
47	.734515	3.43	.074260	7.53	47	.746816	3.38	.101623	7.65
48	.734721	3.45	.074712	7.55	48	.747019	3.38	.102082	7.67
49	.734928	3.45	.075165	7.55	49	.747222	3.37	.102542	7.67
50	.735135	3.45	.075618	7.55	50	.747424	3.38	.103002	7.67
51	9.735342	3.45	10.076071	7.55	51	9.747627	3.38	10.103462	7.67
52	.735549	3.43	.076524	7.55	52	.747830	3.38	.103922	7.67
53	.735755	3.45	.076977	7.57	53	.748033	3.37	.104382	7.68
54	.735962	3.45	.077431	7.55	54	.748235	3.38	.104843	7.67
55	.736169	3.43	.077884	7.57	55	.748438	3.37	.105303	7.68
56	.736375	3.43	.078338	7.57	56	.748640	3.38	.105764	7.67
57	.736581	3.45	.078792	7.55	57	.748843	3.37	.106224	7.68
58	.736788	3.43	.079245	7.57	58	.749045	3.37	.106685	7.68
59	.736994	3.43	.079699	7.57	59	.749247	3.37	.107146	7.68
60	9.737200	3.43	10.080153	7.58	60	9.749449	3.38	10.107607	7.70

64°					65°				
	Vers.	D. 1'.	Ex. sec.	D 1'.		Vers.	D. 1'.	Ex. sec.	D.1'.
0	9.749449	3.38	10.107607	7.70	0	9.761463	3.30	10.135515	7.82
1	.749652	3.37	.108069	7.68	1	.761661	3.32	.135984	7.83
2	.749854	3.37	.108530	7.70	2	.761860	3.30	.136454	7.82
3	.750056	3.37	.108992	7.68	3	.762058	3.30	.136923	7.83
4	.750258	3.35	.109453	7.70	4	.762256	3.30	.137393	7.83
5	.750459	3.37	.109915	7.70	5	.762454	3.30	.137863	7.83
6	.750661	3.37	.110377	7.70	6	.762652	3.30	.138333	7.83
7	.750863	3.37	.110839	7.70	7	.762850	3.28	.138803	7.83
8	.751065	3.35	.111301	7.70	8	.763047	3.30	.139273	7.85
9	.751266	3.37	.111763	7.72	9	.763245	3.30	.139744	7.83
10	.751468	3.35	.112226	7.70	10	.763443	3.30	.140214	7.85
11	9.751669	3.37	10.112688	7.72	11	9.763641	3.28	10.140685	7.85
12	.751871	3.35	.113151	7.72	12	.763838	3.30	.141156	7.85
13	.752072	3.35	.113614	7.72	13	.764036	3.28	.141627	7.85
14	.752273	3.37	.114077	7.72	14	.764233	3.28	.142098	7.85
15	.752475	3.35	.114540	7.72	15	.764430	3.30	.142569	7.87
16	.752676	3.35	.115003	7.72	16	.764628	3.28	.143041	7.85
17	.752877	3.35	.115466	7.72	17	.764825	3.28	.143512	7.87
18	.753078	3.35	.115929	7.73	18	.765022	3.28	.143984	7.87
19	.753279	3.35	.116393	7.73	19	.765219	3.28	.144456	7.87
20	.753480	3.35	.116857	7.73	20	.765416	3.28	.144928	7.87
21	9.753681	3.33	10.117321	7.73	21	9.765613	3.28	10.145400	7.87
22	.753881	3.35	.117785	7.73	22	.765810	3.28	.145872	7.88
23	.754082	3.35	.118249	7.73	23	.766007	3.28	.146345	7.88
24	.754283	3.33	.118713	7.73	24	.766204	3.28	.146818	7.87
25	.754483	3.35	.119177	7.75	25	.766401	3.27	.147290	7.88
26	.754684	3.33	.119642	7.73	26	.766597	3.28	.147763	7.88
27	.754884	3.35	.120106	7.75	27	.766794	3.28	.148236	7.90
28	.755085	3.33	.120571	7.75	28	.766991	3.27	.148710	7.88
29	.755285	3.33	.121036	7.75	29	.767187	3.28	.149183	7.90
30	.755485	3.33	.121501	7.75	30	.767384	3.27	.149657	7.88
31	9.755685	3.35	10.121966	7.75	31	9.767580	3.27	10.150130	7.90
32	.755886	3.33	.122431	7.77	32	.767776	3.27	.150604	7.90
33	.756086	3.33	.122897	7.75	33	.767972	3.28	.151078	7.90
34	.756286	3.33	.123362	7.77	34	.768169	3.27	.151552	7.92
35	.756486	3.32	.123828	7.77	35	.768365	3.27	.152027	7.90
36	.756685	3.33	.124294	7.77	36	.768561	3.27	.152501	7.92
37	.756885	3.33	.124760	7.77	37	.768757	3.27	.152976	7.90
38	.757085	3.33	.125226	7.77	38	.768953	3.27	.153450	7.92
39	.757285	3.32	.125692	7.77	39	.769149	3.25	.153925	7.92
40	.757484	3.33	.126158	7.78	40	.769344	3.27	.154400	7.93
41	9.757684	3.32	10.126625	7.78	41	9.769540	3.27	10.154876	7.92
42	.757883	3.33	.127092	7.77	42	.769736	3.25	.155351	7.92
43	.758083	3.32	.127558	7.78	43	.769931	3.27	.155826	7.93
44	.758282	3.32	.128025	7.78	44	.770127	3.27	.156302	7.93
45	.758481	3.33	.128492	7.80	45	.770323	3.25	.156778	7.93
46	.758681	3.32	.128960	7.78	46	.770518	3.25	.157254	7.93
47	.758880	3.32	.129427	7.78	47	.770713	3.27	.157730	7.93
48	.759079	3.32	.129894	7.80	48	.770909	3.25	.158206	7.95
49	.759278	3.32	.130362	7.80	49	.771104	3.25	.158683	7.93
50	.759477	3.32	.130830	7.80	50	.771299	3.25	.159159	7.95
51	9.759676	3.32	10.131298	7.80	51	9.771494	3.25	10.159636	7.95
52	.759875	3.30	.131766	7.80	52	.771689	3.25	.160113	7.95
53	.760073	3.32	.132234	7.80	53	.771884	3.25	.160590	7.95
54	.760272	3.32	.132702	7.80	54	.772079	3.25	.161067	7.97
55	.760471	3.30	.133170	7.82	55	.772274	3.25	.161545	7.95
56	.760669	3.32	.133639	7.82	56	.772469	3.25	.162022	7.97
57	.760868	3.30	.134108	7.82	57	.772664	3.23	.162500	7.97
58	.761066	3.32	.134577	7.82	58	.772858	3.25	.162978	7.97
59	.761265	3.30	.135046	7.82	59	.773053	3.25	.163456	7.97
60	9.761463	3.30	10.135515	7.82	60	9.773248	3.23	10.163934	7.98

66°					67				
	Vers.	D. 1".	Ex. sec.	D. 1".		Vers.	D. 1".	Ex. sec.	D. 1".
0	9.773248	3.23	10.163934	7.98	0	9.784809	3.18	10.192931	8.15
1	.773442	3.23	.164413	7.97	1	.785000	3.18	.193420	8.13
2	.773636	3.25	.164891	7.98	2	.785191	3.17	.193908	8.15
3	.773831	3.23	.165370	7.98	3	.785381	3.18	.194397	8.15
4	.774025	3.23	.165849	7.98	4	.785572	3.18	.194886	8.17
5	.774219	3.25	.166328	7.98	5	.785763	3.17	.195376	8.15
6	.774414	3.23	.166807	7.98	6	.785953	3.18	.195865	8.17
7	.774608	3.23	.167286	8.00	7	.786144	3.17	.196355	8.17
8	.774802	3.23	.167766	7.98	8	.786334	3.17	.196845	8.17
9	.774996	3.23	.168245	8.00	9	.786524	3.18	.197335	8.17
10	.775190	3.23	.168725	8.00	10	.786715	3.17	.197825	8.17
11	9.775384	3.22	10.169205	8.00	11	9.786905	3.17	10.198315	8.18
12	.775577	3.23	.169685	8.00	12	.787095	3.17	.198806	8.18
13	.775771	3.23	.170165	8.02	13	.787285	3.17	.199297	8.18
14	.775965	3.23	.170646	8.02	14	.787475	3.17	.199788	8.18
15	.776159	3.22	.171127	8.00	15	.787665	3.17	.200279	8.18
16	.776352	3.23	.171607	8.02	16	.787855	3.17	.200770	8.20
17	.776546	3.22	.172088	8.02	17	.788045	3.17	.201262	8.18
18	.776739	3.23	.172569	8.03	18	.788235	3.17	.201753	8.20
19	.776933	3.22	.173051	8.02	19	.788425	3.15	.202245	8.20
20	.777126	3.22	.173532	8.03	20	.788614	3.17	.202737	8.20
21	9.777319	3.22	10.174014	8.03	21	9.788804	3.15	10.203229	8.22
22	.777512	3.22	.174496	8.03	22	.788993	3.17	.203722	8.22
23	.777705	3.23	.174978	8.03	23	.789183	3.15	.204215	8.20
24	.777899	3.22	.175460	8.03	24	.789372	3.17	.204707	8.22
25	.778092	3.22	.175942	8.05	25	.789562	3.15	.205200	8.23
26	.778285	3.20	.176425	8.03	26	.789751	3.15	.205694	8.22
27	.778477	3.22	.176907	8.05	27	.789940	3.17	.206187	8.23
28	.778670	3.22	.177390	8.05	28	.790130	3.15	.206681	8.22
29	.778863	3.22	.177873	8.05	29	.790319	3.15	.207174	8.23
30	.779056	3.20	.178356	8.05	30	.790508	3.15	.207668	8.23
31	9.779248	3.22	10.178839	8.07	31	9.790697	3.15	10.208162	8.25
32	.779441	3.22	.179323	8.07	32	.790886	3.15	.208657	8.23
33	.779634	3.20	.179807	8.05	33	.791075	3.15	.209151	8.25
34	.779826	3.20	.180290	8.07	34	.791264	3.15	.209646	8.25
35	.780018	3.22	.180774	8.08	35	.791453	3.13	.210141	8.25
36	.780211	3.20	.181259	8.07	36	.791641	3.15	.210636	8.25
37	.780403	3.20	.181743	8.07	37	.791830	3.15	.211131	8.27
38	.780595	3.20	.182227	8.08	38	.792019	3.13	.211627	8.27
39	.780787	3.22	.182712	8.08	39	.792207	3.15	.212123	8.25
40	.780980	3.20	.183197	8.08	40	.792396	3.13	.212618	8.28
41	9.781172	3.20	10.183682	8.08	41	9.792584	3.13	10.213115	8.27
42	.781364	3.20	.184167	8.10	42	.792772	3.15	.213611	8.27
43	.781556	3.18	.184653	8.08	43	.792961	3.13	.214107	8.28
44	.781747	3.20	.185138	8.10	44	.793149	3.13	.214604	8.28
45	.781939	3.20	.185624	8.10	45	.793337	3.13	.215101	8.28
46	.782131	3.20	.186110	8.10	46	.793525	3.15	.215598	8.28
47	.782323	3.18	.186596	8.10	47	.793714	3.13	.216095	8.30
48	.782514	3.20	.187082	8.10	48	.793902	3.13	.216593	8.28
49	.782706	3.18	.187568	8.12	49	.794090	3.12	.217090	8.30
50	.782897	3.20	.188055	8.12	50	.794277	3.13	.217588	8.30
51	9.783089	3.18	10.188542	8.12	51	9.794465	3.13	10.218086	8.32
52	.783280	3.18	.189029	8.12	52	.794653	3.13	.218585	8.30
53	.783471	3.20	.189516	8.12	53	.794841	3.12	.219083	8.32
54	.783663	3.18	.190003	8.13	54	.795028	3.13	.219582	8.32
55	.783854	3.18	.190491	8.12	55	.795216	3.13	.220081	8.32
56	.784045	3.18	.190978	8.13	56	.795404	3.12	.220580	8.32
57	.784236	3.18	.191466	8.13	57	.795591	3.13	.221079	8.32
58	.784427	3.18	.191954	8.15	58	.795779	3.12	.221578	8.33
59	.784618	3.18	.192443	8.13	59	.795966	3.12	.222078	8.33
60	9.784809	3.18	10.192931	8.15	60	9.796153	3.13	10.222578	8.33

68°					69°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.796153	3.13	10.222578	8.33	0	9.807286	3.07	10.252957	8.55
1	.796341	3.12	.223078	8.33	1	.807470	3.07	.253470	8.55
2	.796528	3.12	.223578	8.35	2	.807654	3.05	.253983	8.57
3	.796715	3.12	.224079	8.33	3	.807837	3.07	.254497	8.55
4	.796902	3.12	.224579	8.35	4	.808021	3.05	.255010	8.57
5	.797089	3.12	.225080	8.35	5	.808204	3.07	.255524	8.58
6	.797276	3.12	.225581	8.37	6	.808388	3.05	.256039	8.57
7	.797463	3.12	.226083	8.35	7	.808571	3.07	.256553	8.58
8	.797650	3.12	.226584	8.37	8	.808755	3.05	.257068	8.57
9	.797837	3.10	.227086	8.37	9	.808938	3.05	.257582	8.60
10	.798023	3.12	.227588	8.37	10	.809121	3.07	.258098	8.58
11	9.798210	3.12	10.228090	8.37	11	9.809305	3.05	10.258613	8.60
12	.798397	3.10	.228592	8.38	12	.809488	3.05	.259129	8.58
13	.798583	3.12	.229095	8.38	13	.809671	3.05	.259644	8.60
14	.798770	3.10	.229598	8.38	14	.809854	3.05	.260160	8.62
15	.798956	3.10	.230101	8.38	15	.810037	3.05	.260677	8.60
16	.799142	3.12	.230604	8.38	16	.810220	3.05	.261193	8.62
17	.799329	3.10	.231107	8.40	17	.810403	3.03	.261710	8.62
18	.799515	3.10	.231611	8.40	18	.810585	3.05	.262227	8.62
19	.799701	3.10	.232115	8.40	19	.810768	3.05	.262744	8.63
20	.799887	3.12	.232619	8.40	20	.810951	3.05	.263262	8.62
21	9.800074	3.10	10.233123	8.40	21	9.811134	3.03	10.263779	8.63
22	.800260	3.10	.233627	8.42	22	.811316	3.05	.264297	8.63
23	.800446	3.08	.234132	8.42	23	.811499	3.03	.264815	8.65
24	.800631	3.10	.234637	8.42	24	.811681	3.05	.265334	8.65
25	.800817	3.10	.235142	8.42	25	.811864	3.03	.265853	8.63
26	.801003	3.10	.235647	8.43	26	.812046	3.03	.266371	8.67
27	.801189	3.10	.236153	8.42	27	.812228	3.03	.266891	8.65
28	.801375	3.08	.236658	8.43	28	.812410	3.05	.267410	8.67
29	.801560	3.10	.237164	8.43	29	.812593	3.03	.267930	8.65
30	.801746	3.08	.237670	8.45	30	.812775	3.03	.268449	8.68
31	9.801931	3.10	10.238177	8.43	31	9.812957	3.03	10.268970	8.67
32	.802117	3.08	.238683	8.45	32	.813139	3.03	.269490	8.68
33	.802302	3.08	.239190	8.45	33	.813321	3.03	.270011	8.67
34	.802487	3.10	.239697	8.45	34	.813503	3.03	.270531	8.68
35	.802673	3.08	.240204	8.47	35	.813685	3.02	.271052	8.70
36	.802858	3.08	.240712	8.45	36	.813866	3.03	.271574	8.68
37	.803043	3.08	.241219	8.47	37	.814048	3.03	.272095	8.70
38	.803228	3.08	.241727	8.47	38	.814230	3.02	.272617	8.70
39	.803413	3.06	.242235	8.48	39	.814411	3.03	.273139	8.72
40	.803598	3.08	.242744	8.47	40	.814593	3.03	.273662	8.70
41	9.803783	3.08	10.243252	8.48	41	9.814775	3.02	10.274184	8.72
42	.803968	3.08	.243761	8.48	42	.814956	3.02	.274707	8.72
43	.804153	3.08	.244270	8.48	43	.815137	3.03	.275230	8.72
44	.804338	3.07	.244779	8.50	44	.815319	3.02	.275753	8.73
45	.804522	3.08	.245289	8.48	45	.815500	3.02	.276277	8.73
46	.804707	3.08	.245798	8.50	46	.815681	3.02	.276801	8.73
47	.804892	3.07	.246308	8.50	47	.815862	3.03	.277325	8.73
48	.805076	3.08	.246818	8.52	48	.816044	3.02	.277849	8.75
49	.805261	3.07	.247329	8.50	49	.816225	3.02	.278374	8.75
50	.805445	3.07	.247839	8.52	50	.816406	3.02	.278899	8.75
51	9.805629	3.08	10.248350	8.52	51	9.816587	3.00	10.279424	8.75
52	.805814	3.07	.248861	8.52	52	.816767	3.02	.279949	8.77
53	.805998	3.07	.249372	8.52	53	.816948	3.02	.280475	8.75
54	.806182	3.07	.249883	8.53	54	.817129	3.02	.281000	8.78
55	.806366	3.07	.250395	8.53	55	.817310	3.00	.281527	8.77
56	.806550	3.07	.250907	8.53	56	.817490	3.02	.282053	8.78
57	.806734	3.07	.251419	8.55	57	.817671	3.02	.282580	8.77
58	.806918	3.07	.251932	8.53	58	.817852	3.00	.283106	8.80
59	.807102	3.07	.252444	8.55	59	.818032	3.02	.283634	8.78
60	9.807286	3.07	10.252957	8.55	60	9.818213	3.00	10.284161	8.80

70°					71°				
'	Vers.	D. 1".	Ex. sec.	D. 1".	'	Vers.	D. 1".	Ex. sec.	D. 1".
0	9.818213	3.00	10.284161	8.80	0	9.828938	2.95	10.316296	9.07
1	.818393	3.00	.284689	8.78	1	.829115	2.95	.316840	9.08
2	.818573	3.02	.285216	8.82	2	.829292	2.95	.317385	9.07
3	.818754	3.00	.285745	8.80	3	.829469	2.95	.317929	9.10
4	.818934	3.00	.286273	8.82	4	.829646	2.95	.318475	9.08
5	.819114	3.00	.286802	8.82	5	.829823	2.95	.319020	9.08
6	.819294	3.00	.287331	8.82	6	.830000	2.95	.319565	9.10
7	.819474	3.00	.287860	8.82	7	.830177	2.93	.320111	9.12
8	.819654	3.00	.288389	8.83	8	.830353	2.95	.320658	9.10
9	.819834	3.00	.288919	8.83	9	.830530	2.93	.321204	9.12
10	.820014	3.00	.289449	8.83	10	.830706	2.95	.321751	9.12
11	9.820194	3.00	10.289979	8.85	11	9.830883	2.93	10.322298	9.12
12	.820374	2.98	.290510	8.85	12	.831059	2.95	.322845	9.13
13	.820553	3.00	.291041	8.85	13	.831236	2.93	.323393	9.13
14	.820733	3.00	.291572	8.85	14	.831412	2.95	.323941	9.13
15	.820913	2.98	.292103	8.87	15	.831589	2.93	.324489	9.15
16	.821092	3.00	.292635	8.85	16	.831765	2.93	.325038	9.15
17	.821272	2.98	.293166	8.87	17	.831941	2.93	.325587	9.15
18	.821451	3.00	.293698	8.88	18	.832117	2.93	.326136	9.17
19	.821631	2.98	.294231	8.88	19	.832293	2.93	.326686	9.15
20	.821810	2.98	.294764	8.87	20	.832469	2.93	.327235	9.13
21	9.821989	2.98	10.295296	8.90	21	9.832645	2.93	10.327786	9.17
22	.822168	3.00	.295830	8.88	22	.832821	2.93	.328336	9.18
23	.822348	2.98	.296363	8.90	23	.832997	2.93	.328887	9.18
24	.822527	2.98	.296897	8.90	24	.833173	2.93	.329438	9.18
25	.822706	2.98	.297431	8.90	25	.833349	2.93	.329989	9.20
26	.822885	2.98	.297965	8.92	26	.833525	2.92	.330541	9.20
27	.823064	2.98	.298500	8.90	27	.833700	2.93	.331093	9.20
28	.823243	2.97	.299034	8.93	28	.833876	2.92	.331645	9.22
29	.823421	2.98	.299570	8.92	29	.834051	2.93	.332198	9.20
30	.823600	2.98	.300105	8.93	30	.834227	2.92	.332750	9.23
31	9.823779	2.98	10.300641	8.92	31	9.834402	2.93	10.333304	9.22
32	.823958	2.97	.301176	8.95	32	.834578	2.92	.333857	9.23
33	.824136	2.98	.301713	8.93	33	.834753	2.92	.334411	9.23
34	.824315	2.97	.302249	8.95	34	.834928	2.93	.334965	9.25
35	.824493	2.98	.302786	8.95	35	.835104	2.92	.335520	9.23
36	.824672	2.97	.303323	8.95	36	.835279	2.92	.336074	9.25
37	.824850	2.97	.303860	8.97	37	.835454	2.92	.336629	9.27
38	.825028	2.98	.304398	8.97	38	.835629	2.92	.337185	9.27
39	.825207	2.97	.304936	8.97	39	.835804	2.92	.337741	9.27
40	.825385	2.97	.305474	8.97	40	.835979	2.92	.338297	9.27
41	9.825563	2.97	10.306012	8.98	41	9.836154	2.92	10.338853	9.28
42	.825741	2.97	.306551	8.98	42	.836329	2.92	.339410	9.28
43	.825919	2.97	.307090	8.98	43	.836504	2.90	.339967	9.28
44	.826097	2.97	.307629	9.00	44	.836678	2.92	.340524	9.30
45	.826275	2.97	.308169	8.98	45	.836853	2.92	.341082	9.30
46	.826453	2.97	.308708	9.02	46	.837028	2.90	.341640	9.30
47	.826631	2.97	.309249	9.00	47	.837202	2.92	.342198	9.30
48	.826809	2.97	.309789	9.02	48	.837377	2.90	.342756	9.32
49	.826987	2.95	.310330	9.02	49	.837551	2.92	.343315	9.33
50	.827164	2.97	.310871	9.02	50	.837726	2.90	.343875	9.32
51	9.827342	2.95	10.311412	9.02	51	9.837900	2.92	10.344434	9.33
52	.827519	2.97	.311953	9.03	52	.838075	2.90	.344994	9.33
53	.827697	2.95	.312495	9.03	53	.838249	2.90	.345554	9.35
54	.827874	2.97	.313037	9.05	54	.838423	2.90	.346115	9.35
55	.828052	2.95	.313580	9.03	55	.838597	2.90	.346676	9.35
56	.828229	2.95	.314122	9.05	56	.838771	2.90	.347237	9.35
57	.828406	2.97	.314665	9.07	57	.838945	2.90	.347798	9.37
58	.828584	2.95	.315209	9.05	58	.839119	2.90	.348360	9.37
59	.828761	2.95	.315752	9.07	59	.839293	2.90	.348922	9.38
60	9.828938	2.95	10.316296	9.07	60	9.839467	2.90	10.349485	9.38

72°					73°				
	Vers.	D. 1°.	Ex. sec.	D. 1°.		Vers.	D. 1°.	Ex. sec.	D. 1°.
0	9.839467	2.90	10.349485	9.38	0	9.849805	2.85	10.383870	9.73
1	.839641	2.90	.350048	9.38	1	.849976	2.85	.384454	9.73
2	.839815	2.90	.350611	9.40	2	.850147	2.83	.385038	9.75
3	.839989	2.88	.351175	9.38	3	.850317	2.85	.385623	9.77
4	.840162	2.90	.351738	9.42	4	.850488	2.83	.386209	9.75
5	.840336	2.90	.352303	9.40	5	.850658	2.85	.386794	9.77
6	.840510	2.88	.352867	9.42	6	.850829	2.83	.387380	9.78
7	.840683	2.90	.353432	9.42	7	.850999	2.83	.387967	9.78
8	.840857	2.88	.353997	9.43	8	.851169	2.85	.388554	9.78
9	.841030	2.90	.354563	9.43	9	.851340	2.83	.389141	9.78
10	.841204	2.88	.355129	9.43	10	.851510	2.83	.389728	9.80
11	9.841377	2.88	10.355695	9.43	11	9.851680	2.83	10.390316	9.82
12	.841550	2.88	.356261	9.45	12	.851850	2.83	.390905	9.80
13	.841723	2.88	.356828	9.45	13	.852020	2.83	.391493	9.82
14	.841896	2.90	.357395	9.47	14	.852190	2.83	.392082	9.83
15	.842070	2.88	.357963	9.47	15	.852360	2.83	.392672	9.83
16	.842243	2.88	.358531	9.47	16	.852530	2.83	.393262	9.83
17	.842416	2.88	.359099	9.48	17	.852700	2.83	.393852	9.85
18	.842589	2.88	.359668	9.48	18	.852870	2.83	.394443	9.85
19	.842762	2.87	.360237	9.48	19	.853040	2.82	.395034	9.85
20	.842934	2.88	.360806	9.50	20	.853209	2.83	.395625	9.87
21	9.843107	2.88	10.361376	9.50	21	9.853379	2.83	10.396217	9.87
22	.843280	2.88	.361946	9.50	22	.853549	2.82	.396809	9.88
23	.843453	2.87	.362516	9.52	23	.853718	2.83	.397402	9.88
24	.843625	2.88	.363087	9.52	24	.853888	2.82	.397995	9.90
25	.843798	2.87	.363658	9.52	25	.854057	2.83	.398589	9.88
26	.843970	2.88	.364229	9.53	26	.854227	2.82	.399182	9.92
27	.844143	2.87	.364801	9.53	27	.854396	2.82	.399777	9.90
28	.844315	2.88	.365373	9.53	28	.854565	2.83	.400371	9.92
29	.844488	2.87	.365945	9.55	29	.854735	2.82	.400966	9.93
30	.844660	2.87	.366518	9.55	30	.854904	2.82	.401562	9.93
31	9.844832	2.87	10.367091	9.57	31	9.855073	2.82	10.402158	9.93
32	.845004	2.88	.367665	9.57	32	.855242	2.82	.402754	9.95
33	.845177	2.87	.368239	9.57	33	.855411	2.82	.403351	9.95
34	.845349	2.87	.368813	9.57	34	.855580	2.82	.403948	9.95
35	.845521	2.87	.369387	9.58	35	.855749	2.82	.404545	9.97
36	.845693	2.87	.369962	9.60	36	.855918	2.82	.405143	9.98
37	.845865	2.87	.370538	9.58	37	.856087	2.80	.405742	9.97
38	.846037	2.85	.371113	9.60	38	.856255	2.82	.406340	9.98
39	.846208	2.87	.371689	9.62	39	.856424	2.82	.406939	10.00
40	.846380	2.87	.372266	9.60	40	.856593	2.82	.407539	10.00
41	9.846552	2.87	10.372842	9.62	41	9.856762	2.80	10.408139	10.00
42	.846724	2.85	.373419	9.63	42	.856930	2.82	.408739	10.02
43	.846895	2.87	.373997	9.63	43	.857099	2.80	.409340	10.02
44	.847067	2.85	.374575	9.63	44	.857267	2.82	.409941	10.03
45	.847238	2.87	.375153	9.63	45	.857436	2.80	.410543	10.03
46	.847410	2.85	.375731	9.65	46	.857604	2.80	.411145	10.03
47	.847581	2.87	.376310	9.67	47	.857772	2.82	.411747	10.05
48	.847753	2.85	.376890	9.65	48	.857941	2.80	.412350	10.07
49	.847924	2.85	.377469	9.67	49	.858109	2.80	.412954	10.05
50	.848095	2.87	.378049	9.68	50	.858277	2.80	.413557	10.07
51	9.848267	2.85	10.378630	9.67	51	9.858445	2.80	10.414161	10.08
52	.848438	2.85	.379210	9.70	52	.858613	2.80	.414766	10.08
53	.848609	2.85	.379792	9.68	53	.858781	2.80	.415371	10.08
54	.848780	2.85	.380373	9.70	54	.858949	2.80	.415976	10.10
55	.848951	2.85	.380955	9.70	55	.859117	2.80	.416582	10.12
56	.849122	2.85	.381537	9.72	56	.859285	2.80	.417189	10.10
57	.849293	2.85	.382120	9.72	57	.859453	2.80	.417795	10.12
58	.849464	2.83	.382703	9.72	58	.859621	2.78	.418402	10.13
59	.849634	2.85	.383286	9.73	59	.859788	2.80	.419010	10.13
60	9.849805	2.85	10.383870	9.73	60	9.859956	2.80	10.419618	10.13

74°					75°				
'	Vers.	D. 1".	Ex. sec.	D. 1".	'	Vers.	D. 1".	Ex. sec.	D. 1".
0	9.859956	2.80	10.419618	10.13	0	9.869924	2.75	10.456928	10.60
1	.860124	2.78	.420226	10.15	1	.870089	2.73	.457564	10.62
2	.860291	2.80	.420835	10.17	2	.870253	2.75	.458201	10.63
3	.860459	2.78	.421445	10.15	3	.870418	2.73	.458839	10.62
4	.860626	2.80	.422054	10.17	4	.870582	2.75	.459476	10.65
5	.860794	2.78	.422664	10.18	5	.870747	2.73	.460115	10.65
6	.860961	2.78	.423275	10.18	6	.870911	2.75	.460754	10.65
7	.861128	2.80	.423886	10.20	7	.871076	2.73	.461393	10.67
8	.861296	2.78	.424498	10.20	8	.871240	2.73	.462033	10.67
9	.861463	2.78	.425110	10.20	9	.871404	2.73	.462673	10.68
10	.861630	2.78	.425722	10.22	10	.871568	2.73	.463314	10.70
11	9.861797	2.78	10.426335	10.22	11	9.871732	2.73	10.463956	10.70
12	.861964	2.78	.426948	10.23	12	.871896	2.73	.464598	10.70
13	.862131	2.78	.427562	10.23	13	.872060	2.73	.465240	10.72
14	.862298	2.78	.428176	10.23	14	.872224	2.73	.465883	10.73
15	.862465	2.78	.428790	10.27	15	.872388	2.73	.466527	10.73
16	.862632	2.78	.429406	10.25	16	.872552	2.73	.467171	10.73
17	.862799	2.77	.430021	10.27	17	.872716	2.73	.467815	10.75
18	.862965	2.78	.430637	10.27	18	.872880	2.72	.468460	10.77
19	.863132	2.78	.431253	10.28	19	.873043	2.73	.469106	10.77
20	.863299	2.77	.431870	10.30	20	.873207	2.73	.469752	10.77
21	9.863465	2.78	10.432488	10.28	21	9.873371	2.72	10.470398	10.78
22	.863632	2.78	.433105	10.32	22	.873534	2.73	.471045	10.80
23	.863799	2.77	.433724	10.30	23	.873698	2.72	.471693	10.80
24	.863965	2.77	.434342	10.32	24	.873861	2.73	.472341	10.82
25	.864131	2.78	.434961	10.33	25	.874025	2.72	.472990	10.82
26	.864298	2.77	.435581	10.33	26	.874188	2.72	.473639	10.85
27	.864464	2.77	.436201	10.33	27	.874351	2.73	.474289	10.83
28	.864630	2.78	.436821	10.35	28	.874515	2.72	.474939	10.85
29	.864797	2.77	.437442	10.37	29	.874678	2.72	.475590	10.87
30	.864963	2.77	.438064	10.37	30	.874841	2.72	.476242	10.85
31	9.865129	2.77	10.438686	10.37	31	9.875004	2.72	10.476893	10.88
32	.865295	2.77	.439308	10.38	32	.875167	2.72	.477546	10.88
33	.865461	2.77	.439931	10.38	33	.875330	2.72	.478199	10.88
34	.865627	2.77	.440554	10.40	34	.875493	2.72	.478852	10.90
35	.865793	2.77	.441178	10.40	35	.875656	2.72	.479506	10.92
36	.865959	2.75	.441802	10.42	36	.875819	2.72	.480161	10.92
37	.866124	2.77	.442427	10.42	37	.875982	2.72	.480816	10.93
38	.866290	2.77	.443052	10.43	38	.876145	2.72	.481472	10.93
39	.866456	2.77	.443678	10.43	39	.876308	2.70	.482128	10.95
40	.866622	2.75	.444304	10.45	40	.876470	2.72	.482785	10.95
41	9.866787	2.77	10.444931	10.45	41	9.876633	2.72	10.483442	10.97
42	.866953	2.75	.445558	10.45	42	.876796	2.70	.484100	10.98
43	.867118	2.77	.446185	10.47	43	.876958	2.72	.484759	10.98
44	.867284	2.75	.446813	10.48	44	.877121	2.70	.485418	10.98
45	.867449	2.75	.447442	10.48	45	.877283	2.70	.486077	10.98
46	.867614	2.77	.448071	10.48	46	.877445	2.72	.486738	11.00
47	.867780	2.75	.448700	10.50	47	.877608	2.70	.487398	11.02
48	.867945	2.75	.449330	10.52	48	.877770	2.70	.488059	11.03
49	.868110	2.75	.449961	10.52	49	.877932	2.72	.488721	11.05
50	.868275	2.77	.450592	10.52	50	.878095	2.70	.489384	11.05
51	9.868441	2.75	10.451223	10.53	51	9.878257	2.70	10.490047	11.05
52	.868606	2.75	.451855	10.53	52	.878419	2.70	.490710	11.07
53	.868771	2.75	.452487	10.55	53	.878581	2.70	.491374	11.08
54	.868936	2.73	.453120	10.57	54	.878743	2.70	.492039	11.08
55	.869100	2.75	.453754	10.57	55	.878905	2.70	.492704	11.10
56	.869265	2.75	.454388	10.57	56	.879067	2.70	.493370	11.10
57	.869430	2.75	.455022	10.58	57	.879229	2.68	.494036	11.12
58	.869595	2.75	.455657	10.58	58	.879390	2.70	.494703	11.13
59	.869760	2.73	.456292	10.60	59	.879552	2.70	.495371	11.13
60	9.869924	2.75	10.456928	10.60	60	9.879714	2.70	10.496039	11.13

76°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.879714	2.70	10.496039	11.13
1	.879876	2.68	.496707	11.17
2	.880037	2.70	.497377	11.17
3	.880199	2.68	.498047	11.17
4	.880360	2.70	.498717	11.18
5	.880522	2.68	.499388	11.20
6	.880683	2.70	.500060	11.20
7	.880845	2.68	.500732	11.22
8	.881006	2.68	.501405	11.22
9	.881167	2.70	.502078	11.23
10	.881329	2.68	.502752	11.23
11	9.881490	2.68	10.503426	11.27
12	.881651	2.68	.504102	11.25
13	.881812	2.68	.504777	11.28
14	.881973	2.63	.505454	11.28
15	.882134	2.68	.506131	11.28
16	.882295	2.68	.506808	11.30
17	.882456	2.68	.507486	11.32
18	.882617	2.67	.508165	11.32
19	.882777	2.63	.508844	11.33
20	.882938	2.68	.509524	11.35
21	9.883099	2.68	10.510205	11.35
22	.883260	2.67	.510886	11.37
23	.883420	2.68	.511568	11.37
24	.883581	2.67	.512250	11.38
25	.883741	2.68	.512933	11.40
26	.883902	2.67	.513617	11.40
27	.884062	2.68	.514301	11.42
28	.884223	2.67	.514986	11.43
29	.884383	2.67	.515672	11.43
30	.884543	2.67	.516358	11.45
31	9.884703	2.68	10.517045	11.45
32	.884864	2.67	.517732	11.47
33	.885024	2.67	.518420	11.48
34	.885184	2.67	.519109	11.48
35	.885344	2.67	.519798	11.50
36	.885504	2.67	.520488	11.52
37	.885664	2.67	.521179	11.50
38	.885824	2.65	.521870	11.53
39	.885983	2.67	.522562	11.53
40	.886143	2.67	.523254	11.55
41	9.886303	2.67	10.523947	11.57
42	.886463	2.65	.524641	11.57
43	.886622	2.67	.525335	11.58
44	.886782	2.65	.526030	11.60
45	.886941	2.67	.526726	11.62
46	.887101	2.65	.527423	11.62
47	.887260	2.67	.528120	11.62
48	.887420	2.65	.528817	11.65
49	.887579	2.67	.529516	11.65
50	.887739	2.65	.530215	11.65
51	9.887898	2.65	10.530914	11.67
52	.888057	2.65	.531614	11.68
53	.888216	2.65	.532315	11.70
54	.888375	2.65	.533017	11.70
55	.888534	2.65	.533719	11.72
56	.888693	2.65	.534422	11.73
57	.888852	2.65	.535126	11.73
58	.889011	2.65	.535830	11.75
59	.889170	2.65	.536535	11.77
60	9.889329	2.65	10.537241	11.77

77°

	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.889329	2.65	10.537241	11.77
1	.889488	2.65	.537947	11.78
2	.889647	2.63	.538654	11.80
3	.889805	2.65	.539362	11.82
4	.889964	2.65	.540071	11.82
5	.890123	2.63	.540780	11.83
6	.890281	2.65	.541490	11.83
7	.890440	2.63	.542200	11.85
8	.890598	2.65	.542911	11.87
9	.890757	2.63	.543623	11.88
10	.890915	2.63	.544336	11.88
11	9.891073	2.65	10.545049	11.90
12	.891232	2.63	.545763	11.90
13	.891390	2.63	.546477	11.93
14	.891548	2.63	.547193	11.93
15	.891706	2.63	.547909	11.95
16	.891864	2.63	.548626	11.95
17	.892022	2.63	.549343	11.97
18	.892180	2.63	.550061	11.98
19	.892338	2.63	.550780	12.00
20	.892496	2.63	.551500	12.00
21	9.892654	2.63	10.552220	12.02
22	.892812	2.62	.552941	12.03
23	.892969	2.63	.553663	12.03
24	.893127	2.63	.554385	12.07
25	.893285	2.62	.555109	12.07
26	.893442	2.63	.555833	12.07
27	.893600	2.63	.556557	12.10
28	.893758	2.62	.557283	12.10
29	.893915	2.62	.558009	12.12
30	.894072	2.63	.558736	12.12
31	9.894230	2.62	10.559463	12.15
32	.894387	2.62	.560192	12.15
33	.894544	2.63	.560921	12.17
34	.894702	2.62	.561651	12.17
35	.894859	2.62	.562381	12.20
36	.895016	2.62	.563113	12.20
37	.895173	2.62	.563845	12.20
38	.895330	2.62	.564577	12.23
39	.895487	2.62	.565311	12.23
40	.895644	2.62	.566045	12.27
41	9.895801	2.62	10.566781	12.25
42	.895958	2.62	.567516	12.28
43	.896115	2.62	.568253	12.28
44	.896272	2.60	.568990	12.32
45	.896428	2.62	.569729	12.32
46	.896585	2.62	.570468	12.32
47	.896742	2.60	.571207	12.35
48	.896898	2.62	.571948	12.35
49	.897055	2.60	.572689	12.37
50	.897211	2.62	.573431	12.38
51	9.897368	2.60	10.574174	12.38
52	.897524	2.60	.574917	12.42
53	.897680	2.62	.575662	12.42
54	.897837	2.60	.576407	12.43
55	.897993	2.60	.577153	12.45
56	.898149	2.60	.577900	12.45
57	.898305	2.60	.578647	12.48
58	.898461	2.62	.579396	12.48
59	.898618	2.60	.580145	12.50
60	9.898774	2.60	10.580895	12.50

78°					79°				
'	Vers.	D. 1'.	Ex. sec.	D. 1'.	'	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.898774	2.60	10.580895	12.50	0	9.908051	2.55	10.627452	13.40
1	.898930	2.60	.581645	12.53	1	.908204	2.55	.628256	13.40
2	.899086	2.58	.582397	12.53	2	.908357	2.57	.629060	13.43
3	.899241	2.60	.583149	12.57	3	.908511	2.55	.629866	13.45
4	.899397	2.60	.583903	12.57	4	.908664	2.55	.630673	13.45
5	.899553	2.60	.584657	12.57	5	.908817	2.55	.631480	13.48
6	.899709	2.60	.585411	12.60	6	.908970	2.55	.632289	13.48
7	.899865	2.58	.586167	12.60	7	.909123	2.55	.633098	13.52
8	.900020	2.60	.586923	12.63	8	.909276	2.53	.633909	13.52
9	.900176	2.58	.587681	12.63	9	.909428	2.55	.634720	13.55
10	.900331	2.60	.588439	12.65	10	.909581	2.55	.635533	13.55
11	9.900487	2.58	10.589198	12.65	11	9.909734	2.55	10.636346	13.58
12	.900642	2.60	.589957	12.68	12	.909887	2.53	.637161	13.58
13	.900798	2.58	.590718	12.68	13	.910039	2.55	.637976	13.60
14	.900953	2.58	.591479	12.72	14	.910192	2.55	.638792	13.63
15	.901108	2.60	.592242	12.72	15	.910345	2.53	.639610	13.63
16	.901264	2.58	.593005	12.73	16	.910497	2.55	.640428	13.67
17	.901419	2.58	.593769	12.73	17	.910650	2.53	.641248	13.67
18	.901574	2.58	.594533	12.77	18	.910802	2.55	.642068	13.70
19	.901729	2.58	.595299	12.78	19	.910955	2.53	.642890	13.72
20	.901884	2.60	.596066	12.78	20	.911107	2.53	.643713	13.72
21	9.902040	2.58	10.596833	12.80	21	9.911259	2.55	10.644536	13.75
22	.902195	2.58	.597601	12.82	22	.911412	2.53	.645361	13.75
23	.902350	2.57	.598370	12.83	23	.911564	2.53	.646186	13.78
24	.902504	2.58	.599140	12.85	24	.911716	2.53	.647013	13.80
25	.902659	2.58	.599911	12.85	25	.911868	2.53	.647841	13.82
26	.902814	2.58	.600682	12.88	26	.912020	2.53	.648670	13.82
27	.902969	2.58	.601455	12.88	27	.912172	2.53	.649499	13.85
28	.903124	2.57	.602228	12.92	28	.912324	2.53	.650330	13.87
29	.903278	2.58	.603003	12.92	29	.912476	2.53	.651162	13.88
30	.903433	2.58	.603778	12.93	30	.912628	2.53	.651995	13.90
31	9.903588	2.57	10.604554	12.95	31	9.912780	2.53	10.652829	13.92
32	.903742	2.58	.605331	12.95	32	.912932	2.53	.653664	13.95
33	.903897	2.57	.606108	12.98	33	.913084	2.52	.654501	13.95
34	.904051	2.58	.606887	13.00	34	.913235	2.53	.655338	13.97
35	.904206	2.57	.607667	13.00	35	.913387	2.53	.656176	14.00
36	.904360	2.57	.608447	13.02	36	.913539	2.52	.657016	14.00
37	.904514	2.57	.609228	13.03	37	.913690	2.53	.657856	14.03
38	.904668	2.58	.610010	13.07	38	.913842	2.52	.658698	14.03
39	.904823	2.57	.610794	13.07	39	.913993	2.53	.659540	14.07
40	.904977	2.57	.611578	13.08	40	.914145	2.52	.660384	14.08
41	9.905131	2.57	10.612363	13.08	41	9.914296	2.53	10.661229	14.10
42	.905285	2.57	.613148	13.12	42	.914448	2.52	.662075	14.12
43	.905439	2.57	.613935	13.13	43	.914599	2.52	.662922	14.13
44	.905593	2.57	.614723	13.13	44	.914750	2.53	.663770	14.15
45	.905747	2.57	.615511	13.17	45	.914902	2.52	.664619	14.18
46	.905901	2.57	.616301	13.17	46	.915053	2.52	.665470	14.18
47	.906055	2.57	.617091	13.20	47	.915204	2.52	.666321	14.22
48	.906209	2.57	.617883	13.20	48	.915355	2.52	.667174	14.23
49	.906363	2.55	.618675	13.22	49	.915506	2.52	.668028	14.25
50	.906516	2.57	.619468	13.23	50	.915657	2.52	.668883	14.27
51	9.906670	2.57	10.620262	13.25	51	9.915808	2.52	10.669739	14.28
52	.906824	2.55	.621057	13.27	52	.915959	2.52	.670596	14.30
53	.906977	2.57	.621853	13.28	53	.916110	2.52	.671454	14.33
54	.907131	2.55	.622650	13.30	54	.916261	2.52	.672314	14.33
55	.907284	2.57	.623448	13.32	55	.916412	2.50	.673174	14.37
56	.907438	2.55	.624247	13.33	56	.916562	2.52	.674036	14.38
57	.907591	2.55	.625047	13.35	57	.916713	2.52	.674899	14.40
58	.907744	2.57	.625848	13.37	58	.916864	2.50	.675763	14.42
59	.907898	2.55	.626650	13.37	59	.917014	2.52	.676628	14.45
60	9.908051	2.55	10.627452	13.40	60	9.917165	2.52	10.677495	14.45

80°

81°

'	Vers.	D. 1'.	Ex. sec.	D. 1'.	'	Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.917165	2.52	10.677495	14.45	0	9.926119	2.47	10.731786	15.78
1	.917316	2.50	.678362	14.48	1	.926267	2.47	.732733	15.78
2	.917466	2.50	.679231	14.50	2	.926415	2.45	.733680	15.83
3	.917616	2.52	.680101	14.52	3	.926562	2.47	.734630	15.83
4	.917767	2.50	.680972	14.55	4	.926710	2.47	.735580	15.87
5	.917917	2.52	.681845	14.55	5	.926858	2.47	.736532	15.90
6	.918068	2.50	.682718	14.58	6	.927006	2.45	.737486	15.92
7	.918218	2.50	.683593	14.60	7	.927153	2.47	.738441	15.95
8	.918368	2.50	.684469	14.62	8	.927301	2.45	.739398	15.97
9	.918518	2.50	.685346	14.63	9	.927448	2.47	.740356	16.00
10	.918668	2.50	.686224	14.67	10	.927596	2.45	.741316	16.02
11	9.918818	2.50	10.687104	14.68	11	9.927743	2.47	10.742277	16.03
12	.918968	2.50	.687985	14.70	12	.927891	2.45	.743239	16.08
13	.919118	2.50	.688867	14.72	13	.928038	2.45	.744204	16.08
14	.919268	2.50	.689750	14.73	14	.928185	2.47	.745169	16.13
15	.919418	2.50	.690634	14.77	15	.928333	2.45	.746137	16.13
16	.919568	2.50	.691520	14.78	16	.928480	2.45	.747105	16.18
17	.919718	2.50	.692407	14.80	17	.928627	2.45	.748076	16.20
18	.919868	2.50	.693295	14.83	18	.928774	2.45	.749048	16.22
19	.920018	2.48	.694185	14.83	19	.928921	2.45	.750021	16.25
20	.920167	2.50	.695075	14.87	20	.929068	2.45	.750996	16.28
21	9.920317	2.48	10.695967	14.90	21	9.929215	2.45	10.751973	16.30
22	.920466	2.50	.696861	14.90	22	.929362	2.45	.752951	16.33
23	.920616	2.50	.697755	14.93	23	.929509	2.45	.753931	16.35
24	.920766	2.48	.698651	14.95	24	.929656	2.45	.754912	16.38
25	.920915	2.48	.699548	14.97	25	.929803	2.45	.755895	16.42
26	.921064	2.50	.700446	15.00	26	.929950	2.45	.756880	16.43
27	.921214	2.48	.701346	15.02	27	.930097	2.43	.757866	16.47
28	.921363	2.48	.702247	15.03	28	.930243	2.45	.758854	16.50
29	.921512	2.50	.703149	15.05	29	.930390	2.45	.759844	16.52
30	.921662	2.48	.704052	15.08	30	.930537	2.43	.760835	16.53
31	9.921811	2.48	10.704957	15.10	31	9.930683	2.45	10.761827	16.58
32	.921960	2.48	.705863	15.13	32	.930830	2.43	.762822	16.60
33	.922109	2.48	.706771	15.15	33	.930976	2.45	.763818	16.62
34	.922258	2.48	.707680	15.17	34	.931123	2.43	.764815	16.67
35	.922407	2.48	.708590	15.18	35	.931269	2.45	.765815	16.68
36	.922556	2.48	.709501	15.22	36	.931416	2.43	.766816	16.72
37	.922705	2.48	.710414	15.23	37	.931562	2.43	.767819	16.73
38	.922854	2.48	.711328	15.25	38	.931708	2.45	.768823	16.77
39	.923003	2.48	.712243	15.28	39	.931855	2.43	.769829	16.80
40	.923152	2.48	.713160	15.30	40	.932001	2.43	.770837	16.82
41	9.923301	2.47	10.714078	15.33	41	9.932147	2.43	10.771846	16.87
42	.923449	2.48	.714998	15.35	42	.932293	2.43	.772858	16.87
43	.923598	2.48	.715919	15.37	43	.932439	2.43	.773870	16.92
44	.923747	2.47	.716841	15.38	44	.932585	2.43	.774885	16.95
45	.923895	2.48	.717764	15.42	45	.932731	2.43	.775902	16.97
46	.924044	2.47	.718689	15.45	46	.932877	2.43	.776920	17.00
47	.924192	2.48	.719616	15.45	47	.933023	2.43	.777940	17.02
48	.924341	2.47	.720543	15.48	48	.933169	2.43	.778961	17.07
49	.924489	2.47	.721472	15.52	49	.933315	2.42	.779985	17.08
50	.924637	2.48	.722403	15.53	50	.933460	2.43	.781010	17.12
51	9.924786	2.47	10.723335	15.55	51	9.933606	2.43	10.782037	17.13
52	.924934	2.47	.724268	15.58	52	.933752	2.42	.783065	17.18
53	.925082	2.48	.725203	15.60	53	.933897	2.43	.784096	17.20
54	.925231	2.47	.726139	15.63	54	.934043	2.43	.785128	17.23
55	.925379	2.47	.727077	15.65	55	.934189	2.42	.786162	17.27
56	.925527	2.47	.728016	15.67	56	.934334	2.43	.787198	17.30
57	.925675	2.47	.728956	15.70	57	.934480	2.42	.788236	17.33
58	.925823	2.47	.729898	15.73	58	.934625	2.42	.789276	17.35
59	.925971	2.47	.730842	15.73	59	.934770	2.43	.790317	17.40
60	9.926119	2.47	10.731786	15.78	60	9.934916	2.42	10.791361	17.42

82°					83°				
	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.934916	2.42	10.791361	17.42	0	9.943559	2.38	10.857665	19.55
1	.935061	2.42	.792406	17.45	1	.943702	2.38	.858838	19.58
2	.935206	2.43	.793453	17.48	2	.943845	2.37	.860013	19.63
3	.935352	2.42	.794502	17.50	3	.943987	2.38	.861191	19.67
4	.935497	2.42	.795552	17.55	4	.944130	2.38	.862371	19.72
5	.935642	2.43	.796605	17.58	5	.944273	2.37	.863554	19.75
6	.935787	2.42	.797660	17.60	6	.944415	2.38	.864739	19.80
7	.935932	2.42	.798716	17.63	7	.944558	2.37	.865927	19.83
8	.936077	2.42	.799774	17.68	8	.944700	2.38	.867117	19.88
9	.936222	2.42	.800835	17.70	9	.944843	2.37	.868310	19.92
10	.936367	2.42	.801897	17.73	10	.944985	2.37	.869505	19.97
11	9.936512	2.42	10.802961	17.77	11	9.945127	2.38	10.870703	20.00
12	.936657	2.40	.804027	17.80	12	.945270	2.37	.871903	20.05
13	.936801	2.42	.805095	17.83	13	.945412	2.37	.873106	20.10
14	.936946	2.42	.806165	17.87	14	.945554	2.37	.874312	20.13
15	.937091	2.42	.807237	17.90	15	.945696	2.37	.875520	20.18
16	.937236	2.40	.808311	17.93	16	.945838	2.38	.876731	20.23
17	.937380	2.42	.809387	17.97	17	.945981	2.37	.877945	20.27
18	.937525	2.40	.810465	18.00	18	.946123	2.37	.879161	20.30
19	.937669	2.42	.811545	18.03	19	.946265	2.37	.880379	20.37
20	.937814	2.40	.812627	18.07	20	.946407	2.37	.881601	20.40
21	9.937958	2.42	10.813711	18.10	21	9.946549	2.35	10.882825	20.45
22	.938103	2.40	.814797	18.13	22	.946690	2.37	.884052	20.48
23	.938247	2.40	.815885	18.17	23	.946832	2.37	.885281	20.55
24	.938391	2.42	.816975	18.20	24	.946974	2.37	.886514	20.58
25	.938536	2.40	.818067	18.23	25	.947116	2.37	.887749	20.62
26	.938680	2.40	.819161	18.27	26	.947258	2.35	.888986	20.68
27	.938824	2.40	.820257	18.32	27	.947399	2.37	.890227	20.72
28	.938968	2.40	.821356	18.33	28	.947541	2.37	.891470	20.77
29	.939112	2.42	.822456	18.38	29	.947683	2.35	.892716	20.82
30	.939257	2.40	.823559	18.42	30	.947824	2.37	.893965	20.87
31	9.939401	2.40	10.824664	18.43	31	9.947966	2.35	10.895217	20.92
32	.939545	2.38	.825770	18.48	32	.948107	2.37	.896472	20.95
33	.939688	2.40	.826879	18.52	33	.948249	2.35	.897729	21.00
34	.939832	2.40	.827990	18.57	34	.948390	2.35	.898989	21.07
35	.939976	2.40	.829104	18.58	35	.948531	2.37	.900253	21.10
36	.940120	2.40	.830219	18.63	36	.948673	2.35	.901519	21.15
37	.940264	2.40	.831337	18.65	37	.948814	2.35	.902788	21.20
38	.940408	2.38	.832456	18.70	38	.948955	2.35	.904060	21.25
39	.940551	2.40	.833578	18.75	39	.949096	2.35	.905335	21.30
40	.940695	2.40	.834703	18.77	40	.949237	2.37	.906613	21.33
41	9.940839	2.38	10.835829	18.80	41	9.949379	2.35	10.907893	21.40
42	.940982	2.40	.836957	18.85	42	.949520	2.35	.909177	21.45
43	.941126	2.38	.838088	18.88	43	.949661	2.35	.910464	21.50
44	.941269	2.40	.839221	18.93	44	.949802	2.35	.911754	21.55
45	.941413	2.38	.840357	18.95	45	.949943	2.33	.913047	21.60
46	.941556	2.38	.841494	19.00	46	.950083	2.35	.914343	21.65
47	.941699	2.40	.842634	19.03	47	.950224	2.35	.915642	21.70
48	.941843	2.38	.843776	19.08	48	.950365	2.35	.916944	21.75
49	.941986	2.38	.844921	19.12	49	.950506	2.35	.918249	21.82
50	.942129	2.38	.846068	19.15	50	.950647	2.33	.919558	21.85
51	9.942272	2.38	10.847217	19.18	51	9.950787	2.35	10.920869	21.92
52	.942415	2.40	.848368	19.23	52	.950928	2.35	.922184	21.97
53	.942559	2.38	.849522	19.27	53	.951069	2.33	.923502	22.02
54	.942702	2.38	.850678	19.30	54	.951209	2.35	.924823	22.07
55	.942845	2.38	.851836	19.35	55	.951350	2.33	.926147	22.13
56	.942988	2.38	.852997	19.40	56	.951490	2.35	.927475	22.17
57	.943131	2.37	.854161	19.42	57	.951631	2.33	.928805	22.23
58	.943273	2.38	.855326	19.47	58	.951771	2.33	.930139	22.30
59	.943416	2.38	.856494	19.52	59	.951911	2.35	.931477	22.33
60	9.943559	2.38	10.857665	19.55	60	9.952052	2.33	10.932817	22.40

84°

	Vers.	D. 1°.	Ex. sec.	D. 1°.
6	9.952052	2.33	10.932817	23.40
1	.952192	2.33	.934161	23.45
2	.952332	2.35	.935508	23.52
3	.952473	2.33	.936859	23.57
4	.952613	2.33	.938213	23.62
5	.952753	2.33	.939570	23.68
6	.952893	2.33	.940931	23.75
7	.953033	2.33	.942296	23.78
8	.953173	2.33	.943663	23.85
9	.953313	2.33	.945034	23.92
10	.953453	2.33	.946409	23.97
11	9.953593	2.32	10.947787	23.03
12	.953732	2.33	.949169	23.08
13	.953872	2.33	.950554	23.15
14	.954012	2.33	.951943	23.22
15	.954152	2.32	.953336	23.27
16	.954291	2.33	.954732	23.33
17	.954431	2.33	.956132	23.38
18	.954571	2.32	.957535	23.45
19	.954710	2.33	.958942	23.52
20	.954850	2.32	.960353	23.57
21	9.954989	2.33	10.961767	23.65
22	.955129	2.32	.963186	23.70
23	.955268	2.32	.964608	23.77
24	.955407	2.33	.966034	23.82
25	.955547	2.32	.967463	23.90
26	.955686	2.32	.968897	23.95
27	.955825	2.32	.970334	24.02
28	.955964	2.32	.971775	24.10
29	.956103	2.33	.973221	24.15
30	.956243	2.32	.974670	24.22
31	9.956382	2.32	10.976123	24.28
32	.956521	2.32	.977580	24.35
33	.956660	2.32	.979041	24.42
34	.956799	2.30	.980506	24.48
35	.956937	2.32	.981975	24.55
36	.957076	2.32	.983448	24.63
37	.957215	2.32	.984926	24.68
38	.957354	2.32	.986407	24.77
39	.957493	2.30	.987893	24.83
40	.957631	2.32	.989383	24.90
41	9.957770	2.32	10.990877	24.97
42	.957909	2.30	.992375	25.03
43	.958047	2.32	.993877	25.12
44	.958186	2.30	.995384	25.18
45	.958324	2.32	.996895	25.27
46	.958463	2.30	.998411	25.33
47	.958601	2.30	.999931	25.40
48	.958739	2.32	11.001455	25.48
49	.958878	2.30	.002984	25.55
50	.959016	2.30	.004517	25.63
51	9.959154	2.30	11.006055	25.70
52	.959292	2.32	.007597	25.78
53	.959431	2.30	.009144	25.85
54	.959569	2.30	.010695	25.93
55	.959707	2.30	.012251	26.00
56	.959845	2.30	.013811	26.10
57	.959983	2.30	.015377	26.17
58	.960121	2.30	.016947	26.23
59	.960259	2.30	.018521	26.33
60	9.960397	2.30	11.020101	26.40

85°

	Vers.	D. 1°.	Ex. sec.	D. 1°.
0	9.960397	2.30	11.020101	26.40
1	.960535	2.28	.021685	26.48
2	.960672	2.30	.023274	26.57
3	.960810	2.30	.024868	26.65
4	.960948	2.30	.026467	26.73
5	.961086	2.28	.028071	26.80
6	.961223	2.30	.029679	26.90
7	.961361	2.28	.031293	26.98
8	.961498	2.30	.032912	27.07
9	.961636	2.28	.034536	27.13
10	.961773	2.30	.036164	27.23
11	9.961911	2.28	11.037798	27.33
12	.962048	2.30	.039438	27.40
13	.962186	2.28	.041082	27.50
14	.962323	2.28	.042732	27.58
15	.962460	2.28	.044387	27.67
16	.962597	2.30	.046047	27.77
17	.962735	2.28	.047713	27.85
18	.962872	2.28	.049384	27.93
19	.963009	2.28	.051060	28.03
20	.963146	2.28	.052742	28.13
21	9.963283	2.28	11.054430	28.22
22	.963420	2.28	.056123	28.30
23	.963557	2.28	.057821	28.40
24	.963694	2.28	.059525	28.50
25	.963831	2.28	.061235	28.60
26	.963968	2.27	.062951	28.68
27	.964104	2.28	.064672	28.78
28	.964241	2.28	.066399	28.88
29	.964378	2.28	.068132	28.98
30	.964515	2.27	.069871	29.08
31	9.964651	2.28	11.071616	29.18
32	.964788	2.27	.073367	29.28
33	.964924	2.28	.075124	29.38
34	.965061	2.27	.076887	29.48
35	.965197	2.28	.078656	29.58
36	.965334	2.27	.080431	29.68
37	.965470	2.28	.082212	29.80
38	.965607	2.27	.084000	29.90
39	.965743	2.27	.085794	30.00
40	.965879	2.28	.087594	30.12
41	9.966016	2.27	11.089401	30.22
42	.966152	2.27	.091214	30.32
43	.966288	2.27	.093033	30.43
44	.966424	2.27	.094859	30.55
45	.966560	2.27	.096692	30.67
46	.966696	2.27	.098532	30.77
47	.966832	2.27	.100378	30.87
48	.966968	2.27	.102230	31.00
49	.967104	2.27	.104090	31.12
50	.967240	2.27	.105957	31.22
51	9.967376	2.27	11.107830	31.35
52	.967512	2.25	.109711	31.45
53	.967647	2.27	.111598	31.58
54	.967783	2.27	.113493	31.68
55	.967919	2.25	.115394	31.82
56	.968054	2.27	.117303	31.98
57	.968190	2.27	.119219	32.07
58	.968326	2.25	.121143	32.18
59	.968461	2.27	.123074	32.30
60	9.968597	2.25	11.125012	32.43

86°

87°

	Vers.	D. 1'.	Ex. sec.	D. 1'.		Vers.	D. 1'.	Ex. sec.	D. 1'.
0	9.968697	2.25	11.125012	32.43	0	9.976654	2.23	11.257854	42.52
1	.968732	2.27	.126958	32.55	1	.976788	2.22	.260405	42.73
2	.968868	2.25	.128911	32.70	2	.976921	2.22	.262969	42.95
3	.969003	2.25	.130873	32.80	3	.977054	2.22	.265546	43.20
4	.969138	2.27	.132841	32.95	4	.977187	2.22	.268138	43.42
5	.969274	2.25	.134818	33.07	5	.977320	2.20	.270743	43.67
6	.969409	2.25	.136802	33.22	6	.977452	2.22	.273363	43.88
7	.969544	2.25	.138795	33.33	7	.977585	2.22	.275996	44.15
8	.969679	2.25	.140795	33.47	8	.977718	2.22	.278645	44.38
9	.969814	2.25	.142803	33.62	9	.977851	2.22	.281308	44.63
10	.969949	2.25	.144820	33.73	10	.977984	2.20	.283986	44.88
11	9.970084	2.25	11.146844	33.88	11	9.978116	2.22	11.286679	45.13
12	.970219	2.25	.148877	34.02	12	.978249	2.22	.289387	45.38
13	.970354	2.25	.150918	34.17	13	.978382	2.20	.292110	45.65
14	.970489	2.25	.152968	34.30	14	.978514	2.22	.294849	45.92
15	.970624	2.25	.155026	34.43	15	.978647	2.20	.297604	46.17
16	.970759	2.25	.157092	34.60	16	.978779	2.22	.300374	46.45
17	.970894	2.25	.159168	34.73	17	.978912	2.20	.303161	46.72
18	.971029	2.25	.161252	34.87	18	.979044	2.22	.305964	47.00
19	.971164	2.23	.163344	35.03	19	.979177	2.20	.308784	47.27
20	.971298	2.25	.165446	35.17	20	.979309	2.22	.311620	47.55
21	9.971433	2.25	11.167556	35.33	21	9.979442	2.20	11.314473	47.83
22	.971568	2.23	.169676	35.48	22	.979574	2.20	.317343	48.13
23	.971702	2.25	.171805	35.63	23	.979706	2.20	.320231	48.43
24	.971837	2.23	.173943	35.78	24	.979838	2.20	.323137	48.72
25	.971971	2.25	.176090	35.93	25	.979970	2.22	.326060	49.02
26	.972106	2.23	.178246	36.10	26	.980103	2.20	.329001	49.33
27	.972240	2.23	.180412	36.27	27	.980235	2.20	.331961	49.63
28	.972374	2.25	.182588	36.42	28	.980367	2.20	.334939	49.93
29	.972509	2.23	.184773	36.58	29	.980499	2.20	.337935	50.27
30	.972643	2.23	.186968	36.75	30	.980631	2.20	.340951	50.58
31	9.972777	2.25	11.189173	36.90	31	9.980763	2.20	11.343986	50.92
32	.972912	2.23	.191387	37.08	32	.980895	2.18	.347041	51.23
33	.973046	2.23	.193612	37.25	33	.981026	2.20	.350115	51.58
34	.973180	2.23	.195847	37.42	34	.981158	2.20	.353210	51.92
35	.973314	2.23	.198092	37.58	35	.981290	2.20	.356325	52.25
36	.973448	2.23	.200347	37.77	36	.981422	2.20	.359460	52.62
37	.973582	2.23	.202613	37.93	37	.981554	2.18	.362617	52.95
38	.973716	2.23	.204889	38.12	38	.981685	2.20	.365794	53.32
39	.973850	2.23	.207176	38.28	39	.981817	2.20	.368993	53.68
40	.973984	2.23	.209473	38.47	40	.981949	2.18	.372214	54.07
41	9.974118	2.23	11.211781	38.67	41	9.982080	2.20	11.375458	54.42
42	.974252	2.23	.214101	38.83	42	.982212	2.18	.378723	54.80
43	.974386	2.22	.216431	39.03	43	.982343	2.20	.382011	55.20
44	.974519	2.23	.218773	39.20	44	.982475	2.18	.385323	55.58
45	.974653	2.23	.221125	39.42	45	.982606	2.18	.388658	55.97
46	.974787	2.22	.223490	39.58	46	.982737	2.20	.392016	56.38
47	.974920	2.23	.225865	39.80	47	.982869	2.18	.395399	56.80
48	.975054	2.23	.228253	39.98	48	.983000	2.18	.398807	57.20
49	.975188	2.22	.230652	40.18	49	.983131	2.18	.402239	57.62
50	.975321	2.23	.233063	40.38	50	.983262	2.20	.405696	58.07
51	9.975455	2.22	11.235486	40.58	51	9.983394	2.18	11.409180	58.48
52	.975588	2.23	.237921	40.78	52	.983525	2.18	.412689	58.93
53	.975722	2.22	.240368	41.00	53	.983656	2.18	.416225	59.38
54	.975855	2.22	.242828	41.20	54	.983787	2.18	.419788	59.83
55	.975988	2.23	.245300	41.42	55	.983918	2.18	.423378	60.28
56	.976122	2.22	.247785	41.63	56	.984049	2.18	.426995	60.77
57	.976255	2.22	.250283	41.83	57	.984180	2.18	.430641	61.25
58	.976388	2.22	.252793	42.07	58	.984311	2.18	.434316	61.73
59	.976521	2.22	.255317	42.28	59	.984442	2.18	.438020	62.22
60	9.976654	2.23	11.257854	42.52	60	9.984573	2.17	11.441753	62.73

88°					89°				
'	Vers.	D. 1'.	Ex. sec.	$q+l$	'	Vers.	D. 1'.	Ex. sec.	$q+l$
				15.29*					15.30*
0	9.984573	2.17	11.441753	9086	0	9.992354	2.13	11.750498	6801
1	.984703	2.18	.445517	9215	1	.992482	2.15	.757925	6929
2	.984834	2.18	.449311	9345	2	.992611	2.13	.765477	7056
3	.984965	2.18	.453137	9474	3	.992739	2.15	.773158	7184
4	.985096	2.17	.456994	9603	4	.992868	2.13	.780973	7312
5	.985226	2.18	.460883	9732	5	.992996	2.13	.788926	7440
6	.985357	2.17	.464805	9862	6	.993124	2.15	.797022	7567
7	.985487	2.18	.468761	9991	7	.993253	2.13	.805268	7695
8	.985618	2.17	.472751	◆ 120	8	.993381	2.13	.813668	7823
9	.985748	2.18	.476775	0249	9	.993509	2.13	.822229	7950
10	.985879	2.17	.480834	0378	10	.993637	2.13	.830956	8078
11	9.986009	2.18	11.484929	0507	11	9.993765	2.15	11.839858	8205
12	.986140	2.17	.489061	0636	12	.993894	2.13	.848940	8333
13	.986270	2.17	.493230	0765	13	.994022	2.13	.858211	8460
14	.986400	2.18	.497437	0894	14	.994150	2.13	.867679	8588
15	.986531	2.17	.501683	1023	15	.994278	2.13	.877351	8715
16	.986661	2.17	.505968	1152	16	.994406	2.13	.887239	8843
17	.986791	2.17	.510293	1281	17	.994534	2.13	.897350	8970
18	.986921	2.17	.514659	1410	18	.994662	2.12	.907697	9097
19	.987051	2.17	.519066	1539	19	.994789	2.13	.918290	9225
20	.987181	2.17	.523516	1668	20	.994917	2.13	.929141	9352
21	9.987311	2.17	11.528010	1797	21	9.995045	2.13	11.940264	9479
22	.987441	2.17	.532548	1925	22	.995173	2.13	.951672	9607
23	.987571	2.17	.537131	2054	23	.995301	2.12	.963381	9734
24	.987701	2.17	.541760	2183	24	.995428	2.13	.975408	9862
25	.987831	2.17	.546437	2312	25	.995556	2.12	11.987769	9988
26	.987961	2.17	.551161	2440	26	.995683	2.13	12.000485	◆ 116
27	.988091	2.17	.555935	2569	27	.995811	2.13	.013578	0243
28	.988221	2.15	.560759	2698	28	.995939	2.12	.027069	0370
29	.988350	2.17	.565634	2826	29	.996066	2.12	.040984	0497
30	.988480	2.17	.570561	2955	30	.996193	2.13	.055352	0624
31	9.988610	2.15	11.575542	3083	31	9.996321	2.12	12.070202	0751
32	.988739	2.17	.580578	3212	32	.996448	2.13	.085569	0878
33	.988869	2.15	.585670	3340	33	.996576	2.12	.101490	1005
34	.988998	2.17	.590819	3469	34	.996703	2.12	.118008	1132
35	.989128	2.15	.596027	3597	35	.996830	2.12	.135168	1259
36	.989257	2.17	.601295	3726	36	.996957	2.13	.153024	1386
37	.989387	2.15	.606625	3854	37	.997085	2.12	.171634	1513
38	.989516	2.17	.612018	3983	38	.997212	2.12	.191066	1640
39	.989646	2.15	.617475	4111	39	.997339	2.12	.211396	1767
40	.989775	2.15	.622998	4239	40	.997466	2.12	.232712	1894
41	9.989904	2.17	11.628589	4368	41	9.997593	2.12	12.255116	2020
42	.990034	2.15	.634250	4496	42	.997720	2.12	.278723	2147
43	.990163	2.15	.639982	4624	43	.997847	2.12	.303674	2274
44	.990292	2.15	.645788	4752	44	.997974	2.12	.330129	2401
45	.990421	2.15	.651668	4881	45	.998101	2.12	.358285	2527
46	.990550	2.15	.657626	5009	46	.998228	2.12	.388375	2654
47	.990679	2.15	.663663	5137	47	.998355	2.10	.420686	2781
48	.990808	2.15	.669781	5265	48	.998481	2.12	.455575	2907
49	.990937	2.15	.675984	5393	49	.998608	2.12	.493490	3034
50	.991066	2.15	.682272	5521	50	.998735	2.12	.535009	3161
51	9.991195	2.15	11.688649	5649	51	9.998862	2.10	12.580893	3287
52	.991324	2.15	.695117	5777	52	.998988	2.12	.632172	3414
53	.991453	2.15	.701679	5905	53	.999115	2.10	.690291	3540
54	.991582	2.13	.708338	6033	54	.999241	2.12	.757364	3667
55	.991710	2.15	.715097	6161	55	.999368	2.10	.836672	3793
56	.991839	2.15	.721958	6289	56	.999494	2.12	12.933708	3920
57	.991968	2.13	.728925	6417	57	.999621	2.10	13.058774	4046
58	.992096	2.15	.736002	6545	58	.999747	2.12	.234991	4172
59	.992225	2.15	.743192	6673	59	.999874	2.10	.536148	4299
60	9.992354	2.13	11.750498	6801	60	10.000000	2.10	Inf. pos.	4426
				15.30*					15.31*

198 TABLE XXVII.—NATURAL SINES AND COSINES

	0°		1°		2°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.0000000	1.0000000	0.0174524	0.9998477	0.0348995	0.9993908	60
1	.0002909	1.0000000	.0177432	.9998426	.0351902	.9993806	59
2	.0005818	.9999998	.0180341	.9998374	.0354809	.9993704	58
3	.0008727	.9999996	.0183249	.9998321	.0357716	.9993600	57
4	.0011636	.9999993	.0186158	.9998267	.0360623	.9993495	56
5	.0014544	.9999989	.0189066	.9998213	.0363530	.9993390	55
6	.0017453	.9999985	.0191974	.9998157	.0366437	.9993284	54
7	.0020362	.9999979	.0194883	.9998101	.0369344	.9993177	53
8	.0023271	.9999973	.0197791	.9998044	.0372251	.9993069	52
9	.0026180	.9999966	.0200699	.9997986	.0375158	.9992960	51
10	0.0029089	0.9999958	0.0203608	0.9997927	0.0378065	0.9992851	50
11	.0031998	.9999949	.0206516	.9997867	.0380971	.9992740	49
12	.0034907	.9999939	.0209424	.9997807	.0383878	.9992629	48
13	.0037815	.9999928	.0212332	.9997745	.0386785	.9992517	47
14	.0040724	.9999917	.0215241	.9997683	.0389692	.9992404	46
15	.0043633	.9999905	.0218149	.9997620	.0392598	.9992290	45
16	.0046542	.9999892	.0221057	.9997556	.0395505	.9992176	44
17	.0049451	.9999878	.0223965	.9997492	.0398411	.9992060	43
18	.0052360	.9999863	.0226873	.9997426	.0401318	.9991944	42
19	.0055268	.9999847	.0229781	.9997360	.0404224	.9991827	41
20	0.0058177	0.9999831	0.0232690	0.9997292	0.0407131	0.9991709	40
21	.0061086	.9999813	.0235598	.9997224	.0410037	.9991590	39
22	.0063995	.9999795	.0238506	.9997155	.0412944	.9991470	38
23	.0066904	.9999776	.0241414	.9997086	.0415850	.9991350	37
24	.0069813	.9999756	.0244322	.9997015	.0418757	.9991228	36
25	.0072721	.9999736	.0247230	.9996943	.0421663	.9991106	35
26	.0075630	.9999714	.0250138	.9996871	.0424569	.9990983	34
27	.0078539	.9999692	.0253046	.9996798	.0427475	.9990859	33
28	.0081448	.9999668	.0255954	.9996724	.0430382	.9990734	32
29	.0084357	.9999644	.0258862	.9996649	.0433288	.9990609	31
30	0.0087265	0.9999619	0.0261769	0.9996573	0.0436194	0.9990482	30
31	.0090174	.9999593	.0264677	.9996497	.0439100	.9990355	29
32	.0093083	.9999567	.0267585	.9996419	.0442006	.9990227	28
33	.0095992	.9999539	.0270493	.9996341	.0444912	.9990098	27
34	.0098900	.9999511	.0273401	.9996262	.0447818	.9989968	26
35	.0101809	.9999482	.0276309	.9996182	.0450724	.9989837	25
36	.0104718	.9999452	.0279216	.9996101	.0453630	.9989706	24
37	.0107627	.9999421	.0282124	.9996020	.0456536	.9989573	23
38	.0110535	.9999389	.0285032	.9995937	.0459442	.9989440	22
39	.0113444	.9999357	.0287940	.9995854	.0462347	.9989306	21
40	0.0116353	0.9999323	0.0290847	0.9995770	0.0465253	0.9989171	20
41	.0119261	.9999289	.0293755	.9995684	.0468159	.9989035	19
42	.0122170	.9999254	.0296662	.9995599	.0471065	.9988899	18
43	.0125079	.9999218	.0299570	.9995512	.0473970	.9988761	17
44	.0127987	.9999181	.0302478	.9995424	.0476876	.9988623	16
45	.0130896	.9999143	.0305385	.9995336	.0479781	.9988484	15
46	.0133805	.9999105	.0308293	.9995247	.0482687	.9988344	14
47	.0136713	.9999065	.0311200	.9995157	.0485592	.9988203	13
48	.0139622	.9999025	.0314108	.9995066	.0488498	.9988061	12
49	.0142530	.9998984	.0317015	.9994974	.0491403	.9987919	11
50	0.0145439	0.9998942	0.0319922	0.9994881	0.0494308	0.9987775	10
51	.0148348	.9998900	.0322830	.9994788	.0497214	.9987631	9
52	.0151256	.9998856	.0325737	.9994693	.0500119	.9987486	8
53	.0154165	.9998812	.0328644	.9994598	.0503024	.9987340	7
54	.0157073	.9998766	.0331552	.9994502	.0505929	.9987194	6
55	.0159982	.9998720	.0334459	.9994405	.0508835	.9987046	5
56	.0162890	.9998673	.0337366	.9994308	.0511740	.9986898	4
57	.0165799	.9998625	.0340274	.9994209	.0514645	.9986748	3
58	.0168707	.9998577	.0343181	.9994110	.0517550	.9986598	2
59	.0171616	.9998527	.0346088	.9994009	.0520455	.9986447	1
60	0.0174524	0.9998477	0.0348995	0.9993908	0.0523360	0.9986295	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	89°		88°		87°		

TABLE XXVII.—NATURAL SINES AND COSINES 199

	3°		4°		5°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.0523360	0.9986295	0.0697565	0.9975641	0.0871557	0.9961947	60
1	.0526264	.9986143	.0700467	.9975437	.0874455	.9961693	59
2	.0529169	.9985989	.0703368	.9975233	.0877353	.9961438	58
3	.0532074	.9985835	.0706270	.9975028	.0880251	.9961183	57
4	.0534979	.9985680	.0709171	.9974822	.0883148	.9960926	56
5	.0537883	.9985524	.0712073	.9974615	.0886046	.9960669	55
6	.0540788	.9985367	.0714974	.9974408	.0888943	.9960411	54
7	.0543693	.9985209	.0717876	.9974199	.0891840	.9960152	53
8	.0546597	.9985050	.0720777	.9973990	.0894738	.9959892	52
9	.0549502	.9984891	.0723678	.9973780	.0897635	.9959631	51
10	0.0552406	0.9984731	0.0726580	0.9973569	0.0900532	0.9959370	50
11	.0555311	.9984570	.0729481	.9973357	.0903429	.9959107	49
12	.0558215	.9984408	.0732382	.9973145	.0906326	.9958844	48
13	.0561119	.9984245	.0735283	.9972931	.0909223	.9958580	47
14	.0564024	.9984081	.0738184	.9972717	.0912119	.9958315	46
15	.0566928	.9983917	.0741085	.9972502	.0915016	.9958049	45
16	.0569832	.9983751	.0743986	.9972286	.0917913	.9957783	44
17	.0572736	.9983585	.0746887	.9972069	.0920809	.9957515	43
18	.0575640	.9983418	.0749787	.9971851	.0923706	.9957247	42
19	.0578544	.9983250	.0752688	.9971633	.0926602	.9956978	41
20	0.0581448	0.9983082	0.0755589	0.9971413	0.0929499	0.9956708	40
21	.0584352	.9982912	.0758489	.9971193	.0932395	.9956437	39
22	.0587256	.9982742	.0761390	.9970972	.0935291	.9956165	38
23	.0590160	.9982570	.0764290	.9970750	.0938187	.9955893	37
24	.0593064	.9982398	.0767190	.9970528	.0941083	.9955620	36
25	.0595967	.9982225	.0770091	.9970304	.0943979	.9955345	35
26	.0598871	.9982052	.0772991	.9970080	.0946875	.9955070	34
27	.0601775	.9981877	.0775891	.9969854	.0949771	.9954795	33
28	.0604678	.9981701	.0778791	.9969628	.0952666	.9954518	32
29	.0607582	.9981525	.0781691	.9969401	.0955562	.9954240	31
30	0.0610485	0.9981348	0.0784591	0.9969173	0.0958458	0.9953962	30
31	.0613389	.9981170	.0787491	.9968945	.0961353	.9953683	29
32	.0616292	.9980991	.0790391	.9968715	.0964248	.9953403	28
33	.0619196	.9980811	.0793290	.9968485	.0967144	.9953122	27
34	.0622099	.9980631	.0796190	.9968254	.0970039	.9952840	26
35	.0625002	.9980450	.0799090	.9968022	.0972934	.9952557	25
36	.0627905	.9980267	.0801989	.9967789	.0975829	.9952274	24
37	.0630808	.9980084	.0804889	.9967555	.0978724	.9951990	23
38	.0633711	.9979900	.0807788	.9967321	.0981619	.9951705	22
39	.0636614	.9979716	.0810687	.9967085	.0984514	.9951419	21
40	0.0639517	0.9979530	0.0813587	0.9966849	0.0987408	0.9951132	20
41	.0642420	.9979343	.0816486	.9966612	.0990303	.9950844	19
42	.0645323	.9979156	.0819385	.9966374	.0993197	.9950556	18
43	.0648226	.9978968	.0822284	.9966135	.0996092	.9950266	17
44	.0651129	.9978779	.0825183	.9965895	.0998986	.9949976	16
45	.0654031	.9978589	.0828082	.9965655	.1001881	.9949685	15
46	.0656934	.9978399	.0830981	.9965414	.1004775	.9949393	14
47	.0659836	.9978207	.0833880	.9965172	.1007669	.9949101	13
48	.0662739	.9978015	.0836778	.9964929	.1010563	.9948807	12
49	.0665641	.9977821	.0839677	.9964685	.1013457	.9948513	11
50	0.0668544	0.9977627	0.0842576	0.9964440	0.1016351	0.9948217	10
51	.0671446	.9977433	.0845474	.9964195	.1019245	.9947921	9
52	.0674349	.9977237	.0848373	.9963948	.1022138	.9947625	8
53	.0677251	.9977040	.0851271	.9963701	.1025032	.9947327	7
54	.0680153	.9976843	.0854169	.9963453	.1027925	.9947028	6
55	.0683055	.9976645	.0857067	.9963204	.1030819	.9946729	5
56	.0685957	.9976445	.0859966	.9962954	.1033712	.9946428	4
57	.0688859	.9976245	.0862864	.9962704	.1036605	.9946127	3
58	.0691761	.9976045	.0865762	.9962452	.1039499	.9945825	2
59	.0694663	.9975843	.0868660	.9962200	.1042392	.9945523	1
60	0.0697565	0.9975641	0.0871557	0.9961947	0.1045285	0.9945219	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	83°		85°		87°		

200 TABLE XXVII.—NATURAL SINES AND COSINES

	6°		7°		8°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.1045285	0.9945219	0.1218693	0.9925462	0.1391731	0.9902681	60
1	.1048178	.9944914	.1221581	.9925107	.1394612	.9902275	59
2	.1051070	.9944609	.1224468	.9924751	.1397492	.9901869	58
3	.1053963	.9944303	.1227355	.9924394	.1400372	.9901462	57
4	.1056856	.9943996	.1230241	.9924037	.1403252	.9901055	56
5	.1059748	.9943688	.1233128	.9923679	.1406132	.9900646	55
6	.1062641	.9943379	.1236015	.9923319	.1409012	.9900237	54
7	.1065533	.9943070	.1238901	.9922959	.1411892	.9899826	53
8	.1068425	.9942760	.1241788	.9922599	.1414772	.9899415	52
9	.1071318	.9942448	.1244674	.9922237	.1417652	.9899003	51
10	0.1074210	0.9942136	0.1247560	0.9921874	0.1420531	0.9898590	50
11	.1077102	.9941823	.1250446	.9921511	.1423410	.9898177	49
12	.1079994	.9941510	.1253332	.9921147	.1426289	.9897762	48
13	.1082885	.9941195	.1256218	.9920782	.1429168	.9897347	47
14	.1085777	.9940880	.1259104	.9920416	.1432047	.9896931	46
15	.1088669	.9940563	.1261990	.9920049	.1434926	.9896514	45
16	.1091560	.9940246	.1264875	.9919682	.1437805	.9896096	44
17	.1094452	.9939928	.1267761	.9919314	.1440684	.9895677	43
18	.1097343	.9939610	.1270646	.9918944	.1443562	.9895258	42
19	.1100234	.9939290	.1273531	.9918574	.1446440	.9894838	41
20	0.1103126	0.9938969	0.1276416	0.9918204	0.1449319	0.9894416	40
21	.1106017	.9938648	.1279302	.9917832	.1452197	.9893994	39
22	.1108908	.9938326	.1282186	.9917459	.1455075	.9893572	38
23	.1111799	.9938003	.1285071	.9917086	.1457953	.9893148	37
24	.1114689	.9937679	.1287956	.9916712	.1460830	.9892723	36
25	.1117580	.9937355	.1290841	.9916337	.1463708	.9892298	35
26	.1120471	.9937029	.1293725	.9915961	.1466585	.9891872	34
27	.1123361	.9936703	.1296609	.9915584	.1469463	.9891445	33
28	.1126252	.9936375	.1299494	.9915206	.1472340	.9891017	32
29	.1129142	.9936047	.1302378	.9914828	.1475217	.9890588	31
30	0.1132032	0.9935719	0.1305262	0.9914449	0.1478094	0.9890159	30
31	.1134922	.9935389	.1308146	.9914069	.1480971	.9889728	29
32	.1137812	.9935058	.1311030	.9913688	.1483848	.9889297	28
33	.1140702	.9934727	.1313913	.9913306	.1486724	.9888865	27
34	.1143592	.9934395	.1316797	.9912923	.1489601	.9888432	26
35	.1146482	.9934062	.1319681	.9912540	.1492477	.9887998	25
36	.1149372	.9933728	.1322564	.9912155	.1495353	.9887564	24
37	.1152261	.9933393	.1325447	.9911770	.1498230	.9887128	23
38	.1155151	.9933057	.1328330	.9911384	.1501106	.9886692	22
39	.1158040	.9932721	.1331213	.9910997	.1503981	.9886255	21
40	0.1160929	0.9932384	0.1334096	0.9910610	0.1506857	0.9885817	20
41	.1163818	.9932045	.1336979	.9910221	.1509733	.9885378	19
42	.1166707	.9931706	.1339862	.9909832	.1512608	.9884939	18
43	.1169596	.9931367	.1342744	.9909442	.1515484	.9884498	17
44	.1172485	.9931023	.1345627	.9909051	.1518359	.9884057	16
45	.1175374	.9930685	.1348509	.9908659	.1521234	.9883615	15
46	.1178263	.9930342	.1351392	.9908266	.1524109	.9883172	14
47	.1181151	.9929999	.1354274	.9907873	.1526984	.9882728	13
48	.1184040	.9929655	.1357156	.9907478	.1529858	.9882284	12
49	.1186928	.9929310	.1360038	.9907083	.1532733	.9881838	11
50	0.1189816	0.9928965	0.1362919	0.9906687	0.1535607	0.9881392	10
51	.1192704	.9928618	.1365801	.9906290	.1538482	.9880945	9
52	.1195593	.9928271	.1368683	.9905893	.1541356	.9880497	8
53	.1198481	.9927922	.1371564	.9905494	.1544230	.9880048	7
54	.1201368	.9927573	.1374445	.9905095	.1547104	.9879599	6
55	.1204256	.9927224	.1377327	.9904694	.1549978	.9879148	5
56	.1207144	.9926873	.1380208	.9904293	.1552851	.9878697	4
57	.1210031	.9926521	.1383089	.9903891	.1555725	.9878245	3
58	.1212919	.9926169	.1385970	.9903489	.1558598	.9877792	2
59	.1215806	.9925816	.1388850	.9903085	.1561472	.9877338	1
60	0.1218693	0.9925462	0.1391731	0.9902681	0.1564345	0.9876883	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	83°		82°		81°		

TABLE XXVII.—NATURAL SINES AND COSINES 201

	9°		10°		11°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.1564345	0.9876883	0.1736482	0.9848078	0.1908090	0.9816272	60
1	.1567218	.9876428	.1739346	.9847572	.1910945	.9815716	59
2	.1570091	.9875972	.1742211	.9847066	.1913801	.9815160	58
3	.1572963	.9875514	.1745075	.9846558	.1916656	.9814603	57
4	.1575836	.9875057	.1747939	.9846050	.1919510	.9814045	56
5	.1578708	.9874598	.1750803	.9845542	.1922365	.9813486	55
6	.1581581	.9874138	.1753667	.9845032	.1925220	.9812927	54
7	.1584453	.9873678	.1756531	.9844521	.1928074	.9812366	53
8	.1587325	.9873216	.1759395	.9844010	.1930928	.9811805	52
9	.1590197	.9872754	.1762258	.9843498	.1933782	.9811243	51
10	0.1593069	0.9872291	0.1765121	0.9842985	0.1936636	0.9810680	50
11	.1595940	.9871827	.1767984	.9842471	.1939490	.9810116	49
12	.1598812	.9871363	.1770847	.9841956	.1942344	.9809552	48
13	.1601683	.9870897	.1773710	.9841441	.1945197	.9808986	47
14	.1604555	.9870431	.1776573	.9840924	.1948050	.9808420	46
15	.1607426	.9869964	.1779435	.9840407	.1950903	.9807853	45
16	.1610297	.9869496	.1782298	.9839889	.1953756	.9807285	44
17	.1613167	.9869027	.1785160	.9839370	.1956609	.9806716	43
18	.1616038	.9868557	.1788022	.9838850	.1959461	.9806147	42
19	.1618909	.9868087	.1790884	.9838330	.1962314	.9805576	41
20	0.1621779	0.9867615	0.1793746	0.9837808	0.1965166	0.9805005	40
21	.1624650	.9867143	.1796607	.9837286	.1968018	.9804433	39
22	.1627520	.9866670	.1799469	.9836763	.1970870	.9803860	38
23	.1630390	.9866196	.1802330	.9836239	.1973722	.9803286	37
24	.1633260	.9865722	.1805191	.9835715	.1976573	.9802712	36
25	.1636129	.9865246	.1808052	.9835189	.1979425	.9802136	35
26	.1638999	.9864770	.1810913	.9834663	.1982276	.9801560	34
27	.1641868	.9864293	.1813774	.9834136	.1985127	.9800983	33
28	.1644738	.9863815	.1816635	.9833608	.1987978	.9800405	32
29	.1647607	.9863336	.1819495	.9833079	.1990829	.9799827	31
30	0.1650476	0.9862856	0.1822355	0.9832549	0.1993679	0.9799247	30
31	.1653345	.9862375	.1825215	.9832019	.1996530	.9798667	29
32	.1656214	.9861894	.1828075	.9831487	.1999380	.9798086	28
33	.1659082	.9861412	.1830935	.9830955	.2002230	.9797504	27
34	.1661951	.9860929	.1833795	.9830422	.2005080	.9796921	26
35	.1664819	.9860445	.1836654	.9829888	.2007930	.9796337	25
36	.1667687	.9859960	.1839514	.9829353	.2010779	.9795752	24
37	.1670556	.9859475	.1842373	.9828818	.2013629	.9795167	23
38	.1673423	.9858988	.1845232	.9828282	.2016478	.9794581	22
39	.1676291	.9858501	.1848091	.9827744	.2019327	.9793994	21
40	0.1679159	0.9858013	0.1850949	0.9827206	0.2022176	0.9793406	20
41	.1682026	.9857524	.1853808	.9826668	.2025024	.9792818	19
42	.1684894	.9857035	.1856666	.9826128	.2027873	.9792228	18
43	.1687761	.9856544	.1859524	.9825587	.2030721	.9791638	17
44	.1690628	.9856053	.1862382	.9825046	.2033569	.9791047	16
45	.1693495	.9855561	.1865240	.9824504	.2036418	.9790455	15
46	.1696362	.9855068	.1868098	.9823961	.2039265	.9789862	14
47	.1699228	.9854574	.1870956	.9823417	.2042113	.9789268	13
48	.1702095	.9854079	.1873813	.9822873	.2044961	.9788674	12
49	.1704961	.9853583	.1876670	.9822327	.2047808	.9788079	11
50	0.1707828	0.9853087	0.1879528	0.9821781	0.2050655	0.9787483	10
51	.1710694	.9852590	.1882385	.9821234	.2053502	.9786886	9
52	.1713560	.9852092	.1885241	.9820686	.2056349	.9786288	8
53	.1716425	.9851593	.1888098	.9820137	.2059195	.9785689	7
54	.1719291	.9851093	.1890954	.9819587	.2062042	.9785090	6
55	.1722156	.9850593	.1893811	.9819037	.2064888	.9784490	5
56	.1725022	.9850091	.1896667	.9818485	.2067734	.9783889	4
57	.1727887	.9849589	.1899523	.9817933	.2070580	.9783287	3
58	.1730752	.9849086	.1902379	.9817380	.2073426	.9782684	2
59	.1733617	.9848582	.1905234	.9816826	.2076272	.9782080	1
60	0.1736482	0.9848078	0.1908090	0.9816272	0.2079117	0.9781476	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	80°		79°		78°		

202 TABLE XXVII.—NATURAL SINES AND COSINES

	12°		13°		14°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.2079117	0.9781476	0.2249511	0.9743701	0.2419219	0.9702957	60
1	.2081962	.9780871	.2252345	.9743046	.2422041	.9702253	59
2	.2084807	.9780265	.2255179	.9742390	.2424863	.9701548	58
3	.2087652	.9779658	.2258013	.9741734	.2427685	.9700842	57
4	.2090497	.9779050	.2260846	.9741077	.2430507	.9700136	56
5	.2093341	.9778442	.2263680	.9740419	.2433329	.9699428	55
6	.2096186	.9777832	.2266513	.9739760	.2436150	.9698720	54
7	.2099030	.9777222	.2269346	.9739100	.2438971	.9698011	53
8	.2101874	.9776611	.2272179	.9738439	.2441792	.9697301	52
9	.2104718	.9775999	.2275012	.9737778	.2444613	.9696591	51
10	0.2107561	0.9775387	0.2277844	0.9737116	0.2447433	0.9695879	50
11	.2110405	.9774773	.2280677	.9736453	.2450254	.9695167	49
12	.2113248	.9774159	.2283509	.9735789	.2453074	.9694453	48
13	.2116091	.9773544	.2286341	.9735124	.2455894	.9693740	47
14	.2118934	.9772928	.2289172	.9734459	.2458713	.9693025	46
15	.2121777	.9772311	.2292004	.9733793	.2461533	.9692309	45
16	.2124619	.9771693	.2294835	.9733125	.2464352	.9691593	44
17	.2127462	.9771075	.2297666	.9732458	.2467171	.9690875	43
18	.2130304	.9770456	.2300497	.9731789	.2469990	.9690157	42
19	.2133146	.9769836	.2303328	.9731119	.2472809	.9689438	41
20	0.2135988	0.9769215	0.2306159	0.9730449	0.2475627	0.9688719	40
21	.2138829	.9768593	.2308989	.9729777	.2478445	.9687998	39
22	.2141671	.9767970	.2311819	.9729105	.2481263	.9687277	38
23	.2144512	.9767347	.2314649	.9728432	.2484081	.9686555	37
24	.2147353	.9766723	.2317479	.9727759	.2486899	.9685832	36
25	.2150194	.9766098	.2320309	.9727084	.2489716	.9685108	35
26	.2153035	.9765472	.2323138	.9726409	.2492533	.9684383	34
27	.2155876	.9764845	.2325967	.9725733	.2495350	.9683658	33
28	.2158716	.9764218	.2328796	.9725056	.2498167	.9682931	32
29	.2161556	.9763589	.2331625	.9724378	.2500984	.9682204	31
30	0.2164396	0.9762960	0.2334454	0.9723699	0.2503800	0.9681476	30
31	.2167236	.9762330	.2337282	.9723020	.2506616	.9680748	29
32	.2170076	.9761699	.2340110	.9722339	.2509432	.9680018	28
33	.2172915	.9761068	.2342938	.9721658	.2512248	.9679288	27
34	.2175754	.9760435	.2345766	.9720976	.2515063	.9678557	26
35	.2178593	.9759802	.2348594	.9720294	.2517879	.9677825	25
36	.2181432	.9759168	.2351421	.9719610	.2520694	.9677092	24
37	.2184271	.9758533	.2354248	.9718926	.2523508	.9676358	23
38	.2187110	.9757897	.2357075	.9718240	.2526323	.9675624	22
39	.2189948	.9757260	.2359902	.9717554	.2529137	.9674888	21
40	0.2192786	0.9756623	0.2362729	0.9716867	0.2531952	0.9674152	20
41	.2195624	.9755985	.2365555	.9716180	.2534766	.9673415	19
42	.2198462	.9755345	.2368381	.9715491	.2537579	.9672678	18
43	.2201300	.9754706	.2371207	.9714802	.2540393	.9671939	17
44	.2204137	.9754065	.2374033	.9714112	.2543206	.9671200	16
45	.2206974	.9753423	.2376859	.9713421	.2546019	.9670459	15
46	.2209811	.9752781	.2379684	.9712729	.2548832	.9669718	14
47	.2212648	.9752138	.2382510	.9712036	.2551645	.9668977	13
48	.2215485	.9751494	.2385335	.9711343	.2554458	.9668234	12
49	.2218321	.9750849	.2388159	.9710649	.2557270	.9667490	11
50	0.2221158	0.9750203	0.2390984	0.9709953	0.2560082	0.9666746	10
51	.2223994	.9749556	.2393808	.9709258	.2562894	.9666001	9
52	.2226830	.9748909	.2396633	.9708561	.2565705	.9665255	8
53	.2229666	.9748261	.2399457	.9707863	.2568517	.9664508	7
54	.2232501	.9747612	.2402280	.9707165	.2571328	.9663761	6
55	.2235337	.9746962	.2405104	.9706466	.2574139	.9663012	5
56	.2238172	.9746311	.2407927	.9705766	.2576950	.9662263	4
57	.2241007	.9745660	.2410751	.9705065	.2579760	.9661513	3
58	.2243842	.9745008	.2413574	.9704363	.2582570	.9660762	2
59	.2246676	.9744355	.2416396	.9703661	.2585381	.9660011	1
60	0.2249511	0.9743701	0.2419219	0.9702957	0.2588190	0.9659258	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	77°		76°		75°		

TABLE XXVII.—NATURAL SINES AND COSINES 203

	15°		16°		17°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.2588190	0.9659258	0.2756374	0.9612617	0.2923717	0.9563048	60
1	.2591000	.9658505	.2759170	.9611815	.2926499	.9562197	59
2	.2593810	.9657751	.2761965	.9611012	.2929280	.9561345	58
3	.2596619	.9656996	.2764761	.9610208	.2932061	.9560492	57
4	.2599428	.9656240	.2767556	.9609403	.2934842	.9559639	56
5	.2602237	.9655484	.2770352	.9608598	.2937623	.9558785	55
6	.2605045	.9654726	.2773147	.9607792	.2940403	.9557930	54
7	.2607853	.9653968	.2775941	.9606984	.2943183	.9557074	53
8	.2610662	.9653209	.2778736	.9606177	.2945963	.9556218	52
9	.2613469	.9652449	.2781530	.9605368	.2948743	.9555361	51
10	0.2616277	0.9651689	0.2784324	0.9604558	0.2951522	0.9554502	50
11	.2619085	.9650927	.2787118	.9603748	.2954302	.9553643	49
12	.2621892	.9650165	.2789911	.9602937	.2957081	.9552784	48
13	.2624699	.9649402	.2792704	.9602125	.2959859	.9551923	47
14	.2627506	.9648638	.2795497	.9601312	.2962638	.9551062	46
15	.2630312	.9647873	.2798290	.9600499	.2965416	.9550199	45
16	.2633118	.9647108	.2801083	.9599684	.2968194	.9549336	44
17	.2635925	.9646341	.2803875	.9598869	.2970971	.9548473	43
18	.2638730	.9645574	.2806667	.9598053	.2973749	.9547608	42
19	.2641536	.9644806	.2809459	.9597236	.2976526	.9546743	41
20	0.2644342	0.9644037	0.2812251	0.9596418	0.2979303	0.9545876	40
21	.2647147	.9643268	.2815042	.9595600	.2982079	.9545009	39
22	.2649952	.9642497	.2817833	.9594781	.2984856	.9544141	38
23	.2652757	.9641726	.2820624	.9593961	.2987632	.9543273	37
24	.2655561	.9640954	.2823415	.9593140	.2990408	.9542403	36
25	.2658366	.9640181	.2826205	.9592318	.2993184	.9541533	35
26	.2661170	.9639407	.2828995	.9591496	.2995959	.9540662	34
27	.2663973	.9638633	.2831785	.9590672	.2998734	.9539790	33
28	.2666777	.9637858	.2834575	.9589848	.3001509	.9538917	32
29	.2669581	.9637081	.2837364	.9589023	.3004284	.9538044	31
30	0.2672384	0.9636305	0.2840153	0.9588197	0.3007058	0.9537170	30
31	.2675187	.9635527	.2842942	.9587371	.3009832	.9536294	29
32	.2677989	.9634748	.2845731	.9586543	.3012606	.9535418	28
33	.2680792	.9633969	.2848520	.9585715	.3015380	.9534542	27
34	.2683594	.9633189	.2851308	.9584886	.3018153	.9533664	26
35	.2686396	.9632408	.2854096	.9584056	.3020926	.9532786	25
36	.2689198	.9631626	.2856884	.9583226	.3023699	.9531907	24
37	.2692000	.9630843	.2859671	.9582394	.3026471	.9531027	23
38	.2694801	.9630060	.2862458	.9581562	.3029244	.9530146	22
39	.2697602	.9629275	.2865246	.9580729	.3032016	.9529264	21
40	0.2700403	0.9628490	0.2868032	0.9579895	0.3034788	0.9528382	20
41	.2703204	.9627704	.2870819	.9579060	.3037559	.9527499	19
42	.2706004	.9626917	.2873605	.9578225	.3040331	.9526615	18
43	.2708805	.9626130	.2876391	.9577389	.3043102	.9525730	17
44	.2711605	.9625342	.2879177	.9576552	.3045872	.9524844	16
45	.2714404	.9624552	.2881963	.9575714	.3048643	.9523958	15
46	.2717204	.9623762	.2884748	.9574875	.3051413	.9523071	14
47	.2720003	.9622972	.2887533	.9574035	.3054183	.9522183	13
48	.2722802	.9622180	.2890318	.9573195	.3056953	.9521294	12
49	.2725601	.9621387	.2893103	.9572354	.3059723	.9520404	11
50	0.2728400	0.9620594	0.2895887	0.9571512	0.3062492	0.9519514	10
51	.2731198	.9619800	.2898671	.9570669	.3065261	.9518623	9
52	.2733997	.9619005	.2901455	.9569825	.3068030	.9517731	8
53	.2736794	.9618210	.2904239	.9568981	.3070798	.9516838	7
54	.2739592	.9617413	.2907022	.9568136	.3073566	.9515944	6
55	.2742390	.9616616	.2909805	.9567290	.3076334	.9515050	5
56	.2745187	.9615818	.2912588	.9566443	.3079102	.9514154	4
57	.2747984	.9615019	.2915371	.9565595	.3081869	.9513258	3
58	.2750781	.9614219	.2918153	.9564747	.3084636	.9512361	2
59	.2753577	.9613418	.2920935	.9563898	.3087403	.9511464	1
60	0.2756374	0.9612617	0.2923717	0.9563048	0.3090170	0.9510565	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	74°		73°		72°		

204 TABLE XXVII.—NATURAL SINES AND COSINES

	18°		19°		20°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.3090170	0.9510565	0.3255682	0.9455186	0.3420201	0.9396926	60
1	.3092936	.9509666	.3258432	.9454238	.3422935	.9395931	59
2	.3095702	.9508766	.3261182	.9453290	.3425668	.9394935	58
3	.3098468	.9507865	.3263932	.9452341	.3428400	.9393938	57
4	.3101234	.9506963	.3266681	.9451391	.3431133	.9392940	56
5	.3103999	.9506061	.3269430	.9450441	.3433865	.9391942	55
6	.3106764	.9505157	.3272179	.9449489	.3436597	.9390943	54
7	.3109529	.9504253	.3274928	.9448537	.3439329	.9389942	53
8	.3112294	.9503348	.3277676	.9447584	.3442060	.9388942	52
9	.3115058	.9502443	.3280424	.9446630	.3444791	.9387940	51
10	0.3117822	0.9501536	0.3283172	0.9445675	0.3447521	0.9386938	50
11	.3120586	.9500629	.3285919	.9444720	.3450252	.9385934	49
12	.3123349	.9499721	.3288666	.9443764	.3452982	.9384930	48
13	.3126112	.9498812	.3291413	.9442807	.3455712	.9383925	47
14	.3128875	.9497902	.3294160	.9441849	.3458441	.9382920	46
15	.3131638	.9496991	.3296906	.9440890	.3461171	.9381913	45
16	.3134400	.9496080	.3299653	.9439931	.3463900	.9380906	44
17	.3137163	.9495168	.3302398	.9438971	.3466628	.9379898	43
18	.3139925	.9494255	.3305144	.9438010	.3469357	.9378889	42
19	.3142686	.9493341	.3307889	.9437048	.3472085	.9377880	41
20	0.3145448	0.9492426	0.3310634	0.9436085	0.3474812	0.9376869	40
21	.3148209	.9491511	.3313379	.9435122	.3477540	.9375858	39
22	.3150969	.9490595	.3316123	.9434157	.3480267	.9374846	38
23	.3153730	.9489678	.3318867	.9433192	.3482994	.9373833	37
24	.3156490	.9488760	.3321611	.9432227	.3485720	.9372820	36
25	.3159250	.9487842	.3324355	.9431260	.3488447	.9371806	35
26	.3162010	.9486922	.3327098	.9430293	.3491173	.9370790	34
27	.3164770	.9486002	.3329841	.9429324	.3493898	.9369774	33
28	.3167529	.9485081	.3332584	.9428355	.3496624	.9368758	32
29	.3170288	.9484159	.3335326	.9427386	.3499349	.9367740	31
30	0.3173047	0.9483237	0.3338069	0.9426415	0.3502074	0.9366722	30
31	.3175805	.9482313	.3340810	.9425444	.3504798	.9365703	29
32	.3178563	.9481389	.3343552	.9424471	.3507523	.9364683	28
33	.3181321	.9480464	.3346293	.9423498	.3510246	.9363662	27
34	.3184079	.9479538	.3349034	.9422525	.3512970	.9362641	26
35	.3186836	.9478612	.3351775	.9421550	.3515693	.9361618	25
36	.3189593	.9477684	.3354516	.9420575	.3518416	.9360595	24
37	.3192350	.9476756	.3357256	.9419598	.3521139	.9359571	23
38	.3195106	.9475827	.3359996	.9418621	.3523862	.9358547	22
39	.3197863	.9474897	.3362735	.9417644	.3526584	.9357521	21
40	0.3200619	0.9473966	0.3365475	0.9416665	0.3529306	0.9356495	20
41	.3203374	.9473035	.3368214	.9415686	.3532027	.9355468	19
42	.3206130	.9472103	.3370953	.9414705	.3534748	.9354440	18
43	.3208885	.9471170	.3373691	.9413724	.3537469	.9353412	17
44	.3211640	.9470236	.3376429	.9412743	.3540190	.9352382	16
45	.3214395	.9469301	.3379167	.9411760	.3542910	.9351352	15
46	.3217149	.9468366	.3381905	.9410777	.3545630	.9350321	14
47	.3219903	.9467430	.3384642	.9409793	.3548350	.9349289	13
48	.3222657	.9466493	.3387379	.9408808	.3551070	.9348257	12
49	.3225411	.9465555	.3390116	.9407822	.3553789	.9347223	11
50	0.3228164	0.9464616	0.3392852	0.9406835	0.3556508	0.9346189	10
51	.3230917	.9463677	.3395589	.9405848	.3559226	.9345154	9
52	.3233670	.9462736	.3398325	.9404860	.3561944	.9344119	8
53	.3236422	.9461795	.3401060	.9403871	.3564662	.9343082	7
54	.3239174	.9460854	.3403796	.9402881	.3567380	.9342045	6
55	.3241926	.9459911	.3406531	.9401891	.3570097	.9341007	5
56	.3244678	.9458968	.3409265	.9400899	.3572814	.9339968	4
57	.3247429	.9458023	.3412000	.9399907	.3575531	.9338928	3
58	.3250180	.9457078	.3414734	.9398914	.3578248	.9337888	2
59	.3252931	.9456132	.3417468	.9397921	.3580964	.9336846	1
60	0.3255682	0.9455186	0.3420201	0.9396926	0.3583679	0.9335804	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	71°		70°		69°		

	21°		22°		23°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.3583679	0.9335804	0.3746066	0.9271839	0.3907311	0.9205049	60
1	.3586395	.9334761	.3748763	.9270748	.3909989	.9203912	59
2	.3589110	.9333718	.3751459	.9269658	.3912666	.9202774	58
3	.3591825	.9332673	.3754156	.9268566	.3915343	.9201635	57
4	.3594540	.9331628	.3756852	.9267474	.3918019	.9200496	56
5	.3597254	.9330582	.3759547	.9266380	.3920695	.9199356	55
6	.3599968	.9329535	.3762243	.9265286	.3923371	.9198215	54
7	.3602682	.9328488	.3764938	.9264192	.3926047	.9197073	53
8	.3605395	.9327439	.3767632	.9263096	.3928722	.9195931	52
9	.3608108	.9326390	.3770327	.9262000	.3931397	.9194788	51
10	0.3610821	0.9325340	0.3773021	0.9260902	0.3934071	0.9193644	50
11	.3613534	.9324290	.3775714	.9259805	.3936745	.9192499	49
12	.3616246	.9323238	.3778408	.9258706	.3939419	.9191353	48
13	.3618958	.9322186	.3781101	.9257606	.3942093	.9190207	47
14	.3621669	.9321133	.3783794	.9256506	.3944766	.9189060	46
15	.3624380	.9320079	.3786486	.9255405	.3947439	.9187912	45
16	.3627091	.9319024	.3789178	.9254303	.3950111	.9186763	44
17	.3629802	.9317969	.3791870	.9253201	.3952783	.9185614	43
18	.3632512	.9316912	.3794562	.9252097	.3955455	.9184464	42
19	.3635222	.9315855	.3797253	.9250993	.3958127	.9183313	41
20	0.3637932	0.9314797	0.3799944	0.9249888	0.3960798	0.9182161	40
21	.3640641	.9313739	.3802634	.9248782	.3963468	.9181009	39
22	.3643351	.9312679	.3805324	.9247676	.3966139	.9179855	38
23	.3646059	.9311619	.3808014	.9246568	.3968809	.9178701	37
24	.3648768	.9310558	.3810704	.9245460	.3971479	.9177546	36
25	.3651476	.9309496	.3813393	.9244351	.3974148	.9176391	35
26	.3654184	.9308434	.3816082	.9243242	.3976818	.9175234	34
27	.3656891	.9307370	.3818770	.9242131	.3979486	.9174077	33
28	.3659599	.9306306	.3821459	.9241020	.3982155	.9172919	32
29	.3662303	.9305241	.3824147	.9239908	.3984823	.9171760	31
30	0.3665012	0.9304176	0.3826834	0.9238795	0.3987491	0.9170601	30
31	.3667719	.9303109	.3829522	.9237682	.3990158	.9169440	29
32	.3670425	.9302042	.3832209	.9236567	.3992825	.9168279	28
33	.3673130	.9300974	.3834895	.9235452	.3995492	.9167118	27
34	.3675836	.9299905	.3837582	.9234336	.3998158	.9165955	26
35	.3678541	.9298835	.3840268	.9233220	.4000825	.9164791	25
36	.3681246	.9297765	.3842953	.9232102	.4003490	.9163627	24
37	.3683950	.9296694	.3845639	.9230984	.4006156	.9162462	23
38	.3686654	.9295622	.3848324	.9229865	.4008821	.9161297	22
39	.3689358	.9294549	.3851008	.9228745	.4011486	.9160130	21
40	0.3692061	0.9293475	0.3853693	0.9227624	0.4014150	0.9158963	20
41	.3694765	.9292401	.3856377	.9226503	.4016814	.9157795	19
42	.3697468	.9291326	.3859060	.9225381	.4019478	.9156626	18
43	.3700170	.9290250	.3861744	.9224258	.4022141	.9155456	17
44	.3702872	.9289173	.3864427	.9223134	.4024804	.9154286	16
45	.3705574	.9288096	.3867110	.9222010	.4027467	.9153115	15
46	.3708276	.9287017	.3869792	.9220884	.4030129	.9151943	14
47	.3710977	.9285938	.3872474	.9219758	.4032791	.9150770	13
48	.3713678	.9284858	.3875156	.9218632	.4035453	.9149597	12
49	.3716379	.9283778	.3877837	.9217504	.4038114	.9148422	11
50	0.3719079	0.9282696	0.3880518	0.9216375	0.4040775	0.9147247	10
51	.3721780	.9281614	.3883199	.9215246	.4043436	.9146072	9
52	.3724479	.9280531	.3885880	.9214116	.4046096	.9144895	8
53	.3727179	.9279447	.3888560	.9212986	.4048756	.9143718	7
54	.3729878	.9278363	.3891240	.9211854	.4051416	.9142540	6
55	.3732577	.9277277	.3893919	.9210722	.4054075	.9141361	5
56	.3735275	.9276191	.3896598	.9209589	.4056734	.9140181	4
57	.3737973	.9275104	.3899277	.9208455	.4059393	.9139001	3
58	.3740671	.9274016	.3901955	.9207320	.4062051	.9137819	2
59	.3743369	.9272928	.3904633	.9206185	.4064709	.9136637	1
60	0.3746066	0.9271839	0.3907311	0.9205049	0.4067366	0.9135455	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	68°		67°		66°		

206 TABLE XXVII.—NATURAL SINES AND COSINES

	24°		25°		26°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.4067366	0.9135455	0.4226183	0.9063078	0.4383711	0.8987940	60
1	.4070024	.9134271	.4228819	.9061848	.4386326	.8986665	59
2	.4072681	.9133087	.4231455	.9060618	.4388940	.8985389	58
3	.4075337	.9131902	.4234090	.9059386	.4391553	.8984112	57
4	.4077993	.9130716	.4236725	.9058154	.4394166	.8982834	56
5	.4080649	.9129529	.4239360	.9056922	.4396779	.8981555	55
6	.4083305	.9128342	.4241994	.9055688	.4399392	.8980276	54
7	.4085960	.9127154	.4244628	.9054454	.4402004	.8978996	53
8	.4088615	.9125965	.4247262	.9053219	.4404615	.8977715	52
9	.4091269	.9124775	.4249895	.9051983	.4407227	.8976433	51
10	0.4093923	0.9123584	0.4252528	0.9050746	0.4409838	0.8975151	50
11	.4096577	.9122393	.4255161	.9049509	.4412448	.8973868	49
12	.4099230	.9121201	.4257793	.9048271	.4415059	.8972584	48
13	.4101883	.9120008	.4260425	.9047032	.4417668	.8971299	47
14	.4104536	.9118815	.4263056	.9045792	.4420278	.8970014	46
15	.4107189	.9117620	.4265687	.9044551	.4422887	.8968727	45
16	.4109841	.9116425	.4268318	.9043310	.4425496	.8967440	44
17	.4112492	.9115229	.4270949	.9042068	.4428104	.8966153	43
18	.4115144	.9114033	.4273579	.9040825	.4430712	.8964864	42
19	.4117795	.9112835	.4276208	.9039582	.4433319	.8963575	41
20	0.4120445	0.9111637	0.4278838	0.9038338	0.4435927	0.8962285	40
21	.4123096	.9110438	.4281467	.9037093	.4438534	.8960994	39
22	.4125745	.9109238	.4284095	.9035847	.4441140	.8959703	38
23	.4128395	.9108038	.4286723	.9034600	.4443746	.8958411	37
24	.4131044	.9106837	.4289351	.9033353	.4446352	.8957118	36
25	.4133693	.9105635	.4291979	.9032105	.4448957	.8955824	35
26	.4136342	.9104432	.4294606	.9030856	.4451562	.8954529	34
27	.4138990	.9103228	.4297233	.9029606	.4454167	.8953234	33
28	.4141638	.9102024	.4299859	.9028356	.4456771	.8951938	32
29	.4144285	.9100819	.4302485	.9027105	.4459375	.8950641	31
30	0.4146932	0.9099613	0.4305111	0.9025853	0.4461978	0.8949344	30
31	.4149579	.9098406	.4307736	.9024600	.4464581	.8948045	29
32	.4152226	.9097199	.4310361	.9023347	.4467184	.8946746	28
33	.4154872	.9095990	.4312986	.9022092	.4469786	.8945446	27
34	.4157517	.9094781	.4315610	.9020838	.4472388	.8944146	26
35	.4160163	.9093572	.4318234	.9019582	.4474990	.8942844	25
36	.4162808	.9092361	.4320857	.9018325	.4477591	.8941542	24
37	.4165453	.9091150	.4323481	.9017068	.4480192	.8940240	23
38	.4168097	.9089938	.4326103	.9015810	.4482792	.8938936	22
39	.4170741	.9088725	.4328726	.9014551	.4485392	.8937632	21
40	0.4173385	0.9087511	0.4331348	0.9013292	0.4487992	0.8936326	20
41	.4176028	.9086297	.4333970	.9012031	.4490591	.8935021	19
42	.4178671	.9085082	.4336591	.9010770	.4493190	.8933714	18
43	.4181313	.9083866	.4339212	.9009508	.4495789	.8932406	17
44	.4183956	.9082649	.4341832	.9008246	.4498387	.8931098	16
45	.4186597	.9081432	.4344453	.9006982	.4500984	.8929789	15
46	.4189239	.9080214	.4347072	.9005718	.4503582	.8928480	14
47	.4191880	.9078995	.4349692	.9004453	.4506179	.8927169	13
48	.4194521	.9077775	.4352311	.9003188	.4508775	.8925858	12
49	.4197161	.9076554	.4354930	.9001921	.4511372	.8924546	11
50	0.4199801	0.9075333	0.4357548	0.9000654	0.4513967	0.8923234	10
51	.4202441	.9074111	.4360166	.8999386	.4516563	.8921920	9
52	.4205080	.9072888	.4362784	.8998117	.4519158	.8920606	8
53	.4207719	.9071665	.4365401	.8996848	.4521753	.8919291	7
54	.4210358	.9070440	.4368018	.8995578	.4524347	.8917975	6
55	.4212996	.9069215	.4370634	.8994307	.4526941	.8916659	5
56	.4215634	.9067989	.4373251	.8993035	.4529535	.8915342	4
57	.4218272	.9066762	.4375866	.8991763	.4532128	.8914024	3
58	.4220909	.9065535	.4378482	.8990489	.4534721	.8912705	2
59	.4223546	.9064307	.4381097	.8989215	.4537313	.8911385	1
60	0.4226183	0.9063078	0.4383711	0.8987940	0.4539905	0.8910065	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	65°		64°		63°		

TABLE XXVII.—NATURAL SINES AND COSINES 207

	27°		28°		29°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.4539905	0.8910065	0.4694716	0.8829476	0.4848096	0.8746197	60
1	.4542497	.8908744	.4697284	.8828110	.4850640	.8744786	59
2	.4545088	.8907423	.4699852	.8826743	.4853184	.8743375	58
3	.4547679	.8906100	.4702419	.8825376	.4855727	.8741963	57
4	.4550269	.8904777	.4704986	.8824007	.4858270	.8740550	56
5	.4552859	.8903453	.4707553	.8822638	.4860812	.8739137	55
6	.4555449	.8902128	.4710119	.8821269	.4863354	.8737722	54
7	.4558038	.8900803	.4712685	.8819898	.4865895	.8736307	53
8	.4560627	.8899476	.4715250	.8818527	.4868436	.8734891	52
9	.4563216	.8898149	.4717815	.8817155	.4870977	.8733475	51
10	0.4565804	0.8896822	0.4720380	0.8815782	0.4873517	0.8732058	50
11	.4568392	.8895493	.4722944	.8814409	.4876057	.8730640	49
12	.4570979	.8894164	.4725508	.8813035	.4878597	.8729221	48
13	.4573566	.8892834	.4728071	.8811660	.4881136	.8727801	47
14	.4576153	.8891503	.4730634	.8810284	.4883674	.8726381	46
15	.4578739	.8890171	.4733197	.8808907	.4886212	.8724960	45
16	.4581325	.8888839	.4735759	.8807530	.4888750	.8723538	44
17	.4583910	.8887506	.4738321	.8806152	.4891288	.8722116	43
18	.4586496	.8886172	.4740882	.8804774	.4893825	.8720693	42
19	.4589080	.8884838	.4743443	.8803394	.4896361	.8719269	41
20	0.4591665	0.8883503	0.4746004	0.8802014	0.4898897	0.8717844	40
21	.4594248	.8882166	.4748564	.8800633	.4901433	.8716419	39
22	.4596832	.8880830	.4751124	.8799251	.4903968	.8714993	38
23	.4599415	.8879492	.4753683	.8797869	.4906503	.8713566	37
24	.4601998	.8878154	.4756242	.8796486	.4909038	.8712138	36
25	.4604580	.8876815	.4758801	.8795102	.4911572	.8710710	35
26	.4607162	.8875475	.4761359	.8793717	.4914105	.8709281	34
27	.4609744	.8874134	.4763917	.8792332	.4916638	.8707851	33
28	.4612325	.8872793	.4766474	.8790946	.4919171	.8706420	32
29	.4614906	.8871451	.4769031	.8789559	.4921704	.8704989	31
30	0.4617486	0.8870108	0.4771588	0.8788171	0.4924236	0.8703557	30
31	.4620066	.8868765	.4774144	.8786783	.4926767	.8702124	29
32	.4622646	.8867420	.4776700	.8785394	.4929298	.8700691	28
33	.4625225	.8866075	.4779255	.8784004	.4931829	.8699256	27
34	.4627804	.8864730	.4781810	.8782613	.4934359	.8697821	26
35	.4630382	.8863383	.4784364	.8781222	.4936889	.8696386	25
36	.4632960	.8862036	.4786919	.8779830	.4939419	.8694949	24
37	.4635538	.8860688	.4789472	.8778437	.4941948	.8693512	23
38	.4638115	.8859339	.4792026	.8777043	.4944475	.8692074	22
39	.4640692	.8857989	.4794579	.8775649	.4947005	.8690636	21
40	0.4643269	0.8856639	0.4797131	0.8774254	0.4949532	0.8689196	20
41	.4645845	.8855288	.4799683	.8772858	.4952060	.8687756	19
42	.4648420	.8853936	.4802235	.8771462	.4954587	.8686315	18
43	.4650996	.8852584	.4804786	.8770064	.4957113	.8684874	17
44	.4653571	.8851230	.4807337	.8768666	.4959639	.8683431	16
45	.4656145	.8849876	.4809888	.8767268	.4962165	.8681988	15
46	.4658719	.8848522	.4812438	.8765868	.4964690	.8680544	14
47	.4661293	.8847166	.4814987	.8764468	.4967215	.8679100	13
48	.4663866	.8845810	.4817537	.8763067	.4969740	.8677655	12
49	.4666439	.8844453	.4820086	.8761665	.4972264	.8676209	11
50	0.4669012	0.8843095	0.4822634	0.8760263	0.4974787	0.8674762	10
51	.4671584	.8841736	.4825182	.8758859	.4977310	.8673314	9
52	.4674156	.8840377	.4827730	.8757455	.4979833	.8671866	8
53	.4676727	.8839017	.4830277	.8756051	.4982355	.8670417	7
54	.4679298	.8837656	.4832824	.8754645	.4984877	.8668967	6
55	.4681869	.8836295	.4835370	.8753239	.4987399	.8667517	5
56	.4684439	.8834933	.4837916	.8751832	.4989920	.8666066	4
57	.4687009	.8833569	.4840462	.8750425	.4992441	.8664614	3
58	.4689578	.8832206	.4843007	.8749016	.4994961	.8663161	2
59	.4692147	.8830841	.4845552	.8747607	.4997481	.8661708	1
60	0.4694716	0.8829476	0.4848096	0.8746197	0.5000000	0.8660254	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	62°		61°		60°		

208 TABLE XXVII.—NATURAL SINES AND COSINES

	30°		31°		32°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.5000000	0.8660254	0.5150381	0.8571673	0.5299193	0.8480481	60
1	.5002519	.8658799	.5152874	.8570174	.5301659	.8478939	59
2	.5005037	.8657344	.5155367	.8568675	.5304125	.8477397	58
3	.5007556	.8655887	.5157859	.8567175	.5306591	.8475853	57
4	.5010073	.8654430	.5160351	.8565674	.5309057	.8474309	56
5	.5012591	.8652973	.5162842	.8564173	.5311521	.8472765	55
6	.5015107	.8651514	.5165333	.8562671	.5313986	.8471219	54
7	.5017624	.8650055	.5167824	.8561168	.5316450	.8469673	53
8	.5020140	.8648595	.5170314	.8559664	.5318913	.8468126	52
9	.5022655	.8647134	.5172804	.8558160	.5321376	.8466579	51
10	0.5025170	0.8645673	0.5175293	0.8556655	0.5323839	0.8465030	50
11	.5027685	.8644211	.5177782	.8555149	.5326301	.8463481	49
12	.5030199	.8642748	.5180270	.8553643	.5328763	.8461932	48
13	.5032713	.8641284	.5182758	.8552135	.5331224	.8460381	47
14	.5035227	.8639820	.5185246	.8550627	.5333685	.8458830	46
15	.5037740	.8638355	.5187733	.8549119	.5336145	.8457278	45
16	.5040252	.8636889	.5190219	.8547609	.5338605	.8455726	44
17	.5042765	.8635423	.5192705	.8546099	.5341065	.8454172	43
18	.5045278	.8633956	.5195191	.8544588	.5343523	.8452618	42
19	.5047788	.8632488	.5197676	.8543077	.5345982	.8451064	41
20	0.5050298	0.8631019	0.5200161	0.8541564	0.5348440	0.8449508	40
21	.5052809	.8629549	.5202646	.8540051	.5350898	.8447952	39
22	.5055319	.8628079	.5205130	.8538538	.5353355	.8446395	38
23	.5057828	.8626608	.5207613	.8537023	.5355812	.8444838	37
24	.5060338	.8625137	.5210096	.8535508	.5358268	.8443279	36
25	.5062846	.8623664	.5212579	.8533992	.5360724	.8441720	35
26	.5065355	.8622191	.5215061	.8532475	.5363179	.8440161	34
27	.5067863	.8620717	.5217543	.8530958	.5365634	.8438600	33
28	.5070370	.8619243	.5220024	.8529440	.5368089	.8437039	32
29	.5072877	.8617768	.5222505	.8527921	.5370543	.8435477	31
30	0.5075384	0.8616292	0.5224986	0.8526402	0.5372996	0.8433914	30
31	.5077890	.8614815	.5227466	.8524881	.5375449	.8432351	29
32	.5080396	.8613337	.5229945	.8523360	.5377902	.8430787	28
33	.5082901	.8611859	.5232424	.8521839	.5380354	.8429222	27
34	.5085406	.8610380	.5234903	.8520316	.5382806	.8427657	26
35	.5087910	.8608901	.5237381	.8518793	.5385257	.8426091	25
36	.5090414	.8607420	.5239859	.8517269	.5387708	.8424524	24
37	.5092918	.8605939	.5242336	.8515745	.5390158	.8422956	23
38	.5095421	.8604457	.5244813	.8514219	.5392608	.8421388	22
39	.5097924	.8602975	.5247290	.8512693	.5395058	.8419818	21
40	0.5100426	0.8601491	0.5249766	0.8511167	0.5397507	0.8418249	20
41	.5102928	.8600007	.5252241	.8509639	.5399955	.8416679	19
42	.5105429	.8598523	.5254717	.8508111	.5402403	.8415108	18
43	.5107930	.8597037	.5257191	.8506582	.5404851	.8413536	17
44	.5110431	.8595551	.5259665	.8505053	.5407298	.8411963	16
45	.5112931	.8594064	.5262139	.8503522	.5409745	.8410390	15
46	.5115431	.8592576	.5264613	.8501991	.5412191	.8408816	14
47	.5117930	.8591088	.5267085	.8500459	.5414637	.8407241	13
48	.5120429	.8589599	.5269558	.8498927	.5417082	.8405666	12
49	.5122927	.8588109	.5272030	.8497394	.5419527	.8404090	11
50	0.5125425	0.8586619	0.5274502	0.8495860	0.5421971	0.8402513	10
51	.5127923	.8585127	.5276973	.8494325	.5424415	.8400936	9
52	.5130420	.8583635	.5279443	.8492790	.5426859	.8399357	8
53	.5132916	.8582143	.5281914	.8491254	.5429302	.8397778	7
54	.5135413	.8580649	.5284383	.8489717	.5431744	.8396199	6
55	.5137908	.8579155	.5286853	.8488179	.5434187	.8394618	5
56	.5140404	.8577660	.5289322	.8486641	.5436628	.8393037	4
57	.5142899	.8576164	.5291790	.8485102	.5439069	.8391455	3
58	.5145393	.8574668	.5294258	.8483562	.5441510	.8389873	2
59	.5147887	.8573171	.5296726	.8482022	.5443951	.8388290	1
60	0.5150381	0.8571673	0.5299193	0.8480481	0.5446390	0.8386706	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	59°		58°		57°		

TABLE XXVII.—NATURAL SINES AND COSINES 209

	33°		34°		35°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.5446390	0.8386706	0.5591929	0.8290376	0.5735764	0.8191520	60
1	.5448830	.8385121	.5594340	.8288749	.5738147	.8189852	59
2	.5451269	.8383536	.5596751	.8287121	.5740529	.8188182	58
3	.5453707	.8381950	.5599162	.8285493	.5742911	.8186512	57
4	.5456145	.8380363	.5601572	.8283864	.5745292	.8184841	56
5	.5458583	.8378775	.5603981	.8282234	.5747672	.8183169	55
6	.5461020	.8377187	.5606390	.8280603	.5750053	.8181497	54
7	.5463456	.8375598	.5608798	.8278972	.5752432	.8179824	53
8	.5465892	.8374009	.5611206	.8277340	.5754811	.8178151	52
9	.5468328	.8372418	.5613614	.8275708	.5757190	.8176476	51
10	0.5470763	0.8370827	0.5616021	0.8274074	0.5759568	0.8174801	50
11	.5473198	.8369236	.5618428	.8272440	.5761946	.8173125	49
12	.5475632	.8367643	.5620834	.8270806	.5764323	.8171449	48
13	.5478066	.8366050	.5623239	.8269170	.5766700	.8169772	47
14	.5480499	.8364456	.5625645	.8267534	.5769076	.8168094	46
15	.5482932	.8362862	.5628049	.8265897	.5771452	.8166416	45
16	.5485365	.8361266	.5630453	.8264260	.5773827	.8164736	44
17	.5487797	.8359670	.5632857	.8262622	.5776202	.8163056	43
18	.5490228	.8358074	.5635260	.8260983	.5778576	.8161376	42
19	.5492659	.8356476	.5637663	.8259343	.5780950	.8159695	41
20	0.5495090	0.8354878	0.5640066	0.8257703	0.5783323	0.8158013	40
21	.5497520	.8353279	.5642467	.8256062	.5785696	.8156330	39
22	.5499950	.8351680	.5644869	.8254420	.5788069	.8154647	38
23	.5502379	.8350080	.5647270	.8252778	.5790440	.8152963	37
24	.5504807	.8348479	.5649670	.8251135	.5792812	.8151278	36
25	.5507236	.8346877	.5652070	.8249491	.5795183	.8149593	35
26	.5509663	.8345275	.5654469	.8247847	.5797553	.8147906	34
27	.5512091	.8343672	.5656868	.8246202	.5799923	.8146220	33
28	.5514518	.8342068	.5659267	.8244556	.5802292	.8144532	32
29	.5516944	.8340463	.5661665	.8242909	.5804661	.8142844	31
30	0.5519370	0.8338858	0.5664062	0.8241262	0.5807030	0.8141155	30
31	.5521795	.8337252	.5666459	.8239614	.5809397	.8139466	29
32	.5524220	.8335646	.5668856	.8237965	.5811765	.8137775	28
33	.5526645	.8334038	.5671252	.8236316	.5814132	.8136084	27
34	.5529069	.8332430	.5673648	.8234666	.5816498	.8134393	26
35	.5531492	.8330822	.5676043	.8233015	.5818864	.8132701	25
36	.5533915	.8329212	.5678437	.8231364	.5821230	.8131008	24
37	.5536338	.8327602	.5680832	.8229712	.5823595	.8129314	23
38	.5538760	.8325991	.5683225	.8228059	.5825959	.8127620	22
39	.5541182	.8324380	.5685619	.8226405	.5828323	.8125925	21
40	0.5543603	0.8322768	0.5688011	0.8224751	0.5830687	0.8124229	20
41	.5546024	.8321155	.5690403	.8223096	.5833050	.8122532	19
42	.5548444	.8319541	.5692795	.8221440	.5835412	.8120835	18
43	.5550864	.8317927	.5695187	.8219784	.5837774	.8119137	17
44	.5553283	.8316312	.5697577	.8218127	.5840136	.8117439	16
45	.5555702	.8314696	.5699968	.8216469	.5842497	.8115740	15
46	.5558121	.8313080	.5702357	.8214811	.5844857	.8114040	14
47	.5560539	.8311463	.5704747	.8213152	.5847217	.8112339	13
48	.5562956	.8309845	.5707136	.8211492	.5849577	.8110638	12
49	.5565373	.8308226	.5709524	.8209832	.5851936	.8108936	11
50	0.5567790	0.8306607	0.5711912	0.8208170	0.5854294	0.8107234	10
51	.5570206	.8304987	.5714299	.8206509	.5856652	.8105530	9
52	.5572621	.8303366	.5716686	.8204846	.5859010	.8103826	8
53	.5575036	.8301745	.5719073	.8203183	.5861367	.8102122	7
54	.5577451	.8300123	.5721459	.8201519	.5863724	.8100416	6
55	.5579865	.8298500	.5723844	.8199854	.5866080	.8098710	5
56	.5582279	.8296877	.5726229	.8198189	.5868435	.8097004	4
57	.5584692	.8295252	.5728614	.8196523	.5870790	.8095296	3
58	.5587105	.8293628	.5730998	.8194856	.5873145	.8093588	2
59	.5589517	.8292002	.5733381	.8193189	.5875499	.8091879	1
60	0.5591929	0.8290376	0.5735764	0.8191520	0.5877853	0.8090170	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	56°		55°		54°		

210 TABLE XXVII.—NATURAL SINES AND COSINES

	36°		37°		38°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.5877853	0.8090170	0.6018150	0.7986355	0.6156615	0.7880108	60
1	.5880206	.8088460	.6020473	.7984604	.6158907	.7878316	59
2	.5882558	.8086749	.6022795	.7982853	.6161198	.7876524	58
3	.5884910	.8085037	.6025117	.7981100	.6163489	.7874732	57
4	.5887262	.8083325	.6027439	.7979347	.6165780	.7872939	56
5	.5889613	.8081612	.6029760	.7977594	.6168069	.7871145	55
6	.5891964	.8079899	.6032080	.7975839	.6170359	.7869350	54
7	.5894314	.8078185	.6034400	.7974084	.6172648	.7867555	53
8	.5896663	.8076470	.6036719	.7972329	.6174936	.7865759	52
9	.5899012	.8074754	.6039038	.7970572	.6177224	.7863963	51
10	0.5901361	0.8073038	0.6041356	0.7968815	0.6179511	0.7862165	50
11	.5903709	.8071321	.6043674	.7967058	.6181798	.7860367	49
12	.5906057	.8069603	.6045991	.7965299	.6184084	.7858569	48
13	.5908404	.8067885	.6048308	.7963540	.6186370	.7856770	47
14	.5910750	.8066166	.6050624	.7961780	.6188655	.7854970	46
15	.5913096	.8064446	.6052940	.7960020	.6190939	.7853169	45
16	.5915442	.8062726	.6055255	.7958259	.6193224	.7851368	44
17	.5917787	.8061005	.6057570	.7956497	.6195507	.7849566	43
18	.5920132	.8059283	.6059884	.7954735	.6197790	.7847764	42
19	.5922476	.8057560	.6062198	.7952972	.6200073	.7845961	41
20	0.5924819	0.8055837	0.6064511	0.7951208	0.6202355	0.7844157	40
21	.5927163	.8054113	.6066824	.7949444	.6204636	.7842352	39
22	.5929505	.8052389	.6069136	.7947678	.6206917	.7840547	38
23	.5931847	.8050664	.6071447	.7945913	.6209198	.7838741	37
24	.5934189	.8048938	.6073758	.7944146	.6211478	.7836935	36
25	.5936530	.8047211	.6076069	.7942379	.6213757	.7835127	35
26	.5938871	.8045484	.6078379	.7940611	.6216036	.7833320	34
27	.5941211	.8043756	.6080689	.7938843	.6218313	.7831511	33
28	.5943550	.8042028	.6082998	.7937074	.6220592	.7829702	32
29	.5945889	.8040299	.6085306	.7935304	.6222870	.7827892	31
30	0.5948228	0.8038569	0.6087614	0.7933533	0.6225146	0.7826082	30
31	.5950566	.8036838	.6089922	.7931762	.6227423	.7824270	29
32	.5952904	.8035107	.6092229	.7929990	.6229698	.7822459	28
33	.5955241	.8033375	.6094535	.7928218	.6231974	.7820646	27
34	.5957577	.8031642	.6096841	.7926445	.6234248	.7818833	26
35	.5959913	.8029909	.6099147	.7924671	.6236522	.7817019	25
36	.5962249	.8028175	.6101452	.7922896	.6238796	.7815205	24
37	.5964584	.8026440	.6103756	.7921121	.6241069	.7813390	23
38	.5966918	.8024705	.6106060	.7919345	.6243342	.7811574	22
39	.5969252	.8022969	.6108363	.7917569	.6245614	.7809757	21
40	0.5971586	0.8021232	0.6110666	0.7915792	0.6247885	0.7807940	20
41	.5973919	.8019495	.6112969	.7914014	.6250156	.7806123	19
42	.5976251	.8017756	.6115270	.7912235	.6252427	.7804304	18
43	.5978583	.8016018	.6117572	.7910456	.6254696	.7802485	17
44	.5980915	.8014278	.6119873	.7908676	.6256966	.7800665	16
45	.5983246	.8012538	.6122173	.7906896	.6259235	.7798845	15
46	.5985577	.8010797	.6124473	.7905115	.6261503	.7797024	14
47	.5987906	.8009056	.6126772	.7903333	.6263771	.7795202	13
48	.5990236	.8007314	.6129071	.7901550	.6266038	.7793380	12
49	.5992565	.8005571	.6131369	.7899767	.6268305	.7791557	11
50	0.5994893	0.8003827	0.6133666	0.7897983	0.6270571	0.7789733	10
51	.5997221	.8002083	.6135964	.7896198	.6272837	.7787909	9
52	.5999549	.8000338	.6138260	.7894413	.6275102	.7786084	8
53	.6001876	.7998593	.6140556	.7892627	.6277366	.7784258	7
54	.6004202	.7996847	.6142852	.7890841	.6279631	.7782431	6
55	.6006528	.7995100	.6145147	.7889054	.6281894	.7780604	5
56	.6008854	.7993352	.6147442	.7887266	.6284157	.7778777	4
57	.6011179	.7991604	.6149736	.7885477	.6286420	.7776949	3
58	.6013503	.7989855	.6152029	.7883688	.6288682	.7775120	2
59	.6015827	.7988105	.6154322	.7881898	.6290943	.7773290	1
60	0.6018150	0.7986355	0.6156615	0.7880108	0.6293204	0.7771460	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	53°		52°		51°		

TABLE XXVII.—NATURAL SINES AND COSINES 211

	39°		40°		41°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.6293204	0.7771460	0.6427876	0.7660444	0.6560590	0.7547096	60
1	.6295464	.7769629	.6430104	.7658574	.6562785	.7545187	59
2	.6297724	.7767797	.6432332	.7656704	.6564980	.7543278	58
3	.6299983	.7765965	.6434559	.7654832	.6567174	.7541368	57
4	.6302242	.7764132	.6436785	.7652960	.6569367	.7539457	56
5	.6304500	.7762298	.6439011	.7651087	.6571560	.7537546	55
6	.6306758	.7760464	.6441236	.7649214	.6573752	.7535634	54
7	.6309015	.7758629	.6443461	.7647340	.6575944	.7533721	53
8	.6311272	.7756794	.6445685	.7645465	.6578135	.7531808	52
9	.6313528	.7754957	.6447909	.7643590	.6580326	.7529894	51
10	0.6315784	0.7753121	0.6450132	0.7641714	0.6582516	0.7527980	50
11	.6318039	.7751283	.6452355	.7639838	.6584706	.7526065	49
12	.6320293	.7749445	.6454577	.7637960	.6586895	.7524149	48
13	.6322547	.7747606	.6456798	.7636082	.6589083	.7522233	47
14	.6324800	.7745767	.6459019	.7634204	.6591271	.7520316	46
15	.6327053	.7743926	.6461240	.7632325	.6593458	.7518398	45
16	.6329306	.7742086	.6463460	.7630445	.6595645	.7516480	44
17	.6331557	.7740244	.6465679	.7628564	.6597831	.7514561	43
18	.6333809	.7738402	.6467898	.7626683	.6600017	.7512641	42
19	.6336059	.7736559	.6470116	.7624802	.6602202	.7510721	41
20	0.6338310	0.7734716	0.6472334	0.7622919	0.6604386	0.7508800	40
21	.6340559	.7732872	.6474551	.7621036	.6606570	.7506879	39
22	.6342803	.7731027	.6476767	.7619152	.6608754	.7504957	38
23	.6345057	.7729182	.6478984	.7617268	.6610936	.7503034	37
24	.6347305	.7727336	.6481199	.7615383	.6613119	.7501111	36
25	.6349553	.7725493	.6483414	.7613497	.6615300	.7499187	35
26	.6351800	.7723642	.6485628	.7611611	.6617482	.7497262	34
27	.6354046	.7721794	.6487842	.7609724	.6619662	.7495337	33
28	.6356292	.7719945	.6490056	.7607837	.6621842	.7493411	32
29	.6358537	.7718096	.6492268	.7605949	.6624022	.7491484	31
30	0.6360782	0.7716246	0.6494480	0.7604060	0.6626200	0.7489557	30
31	.6363026	.7714395	.6496692	.7602170	.6628379	.7487629	29
32	.6365270	.7712544	.6498903	.7600280	.6630557	.7485701	28
33	.6367513	.7710692	.6501114	.7598389	.6632734	.7483772	27
34	.6369756	.7708840	.6503324	.7596498	.6634910	.7481842	26
35	.6371998	.7706986	.6505533	.7594606	.6637087	.7479912	25
36	.6374240	.7705132	.6507742	.7592713	.6639262	.7477981	24
37	.6376481	.7703278	.6509951	.7590820	.6641437	.7476049	23
38	.6378721	.7701423	.6512158	.7588926	.6643612	.7474117	22
39	.6380961	.7699567	.6514366	.7587031	.6645785	.7472184	21
40	0.6383201	0.7697710	0.6516572	0.7585136	0.6647959	0.7470251	20
41	.6385440	.7695853	.6518778	.7583240	.6650131	.7468317	19
42	.6387678	.7693996	.6520984	.7581343	.6652304	.7466382	18
43	.6389916	.7692137	.6523189	.7579446	.6654475	.7464446	17
44	.6392153	.7690278	.6525394	.7577548	.6656646	.7462510	16
45	.6394390	.7688418	.6527598	.7575650	.6658817	.7460574	15
46	.6396626	.7686558	.6529801	.7573751	.6660987	.7458636	14
47	.6398862	.7684697	.6532004	.7571851	.6663156	.7456699	13
48	.6401097	.7682835	.6534206	.7569951	.6665325	.7454760	12
49	.6403332	.7680973	.6536408	.7568050	.6667493	.7452821	11
50	0.6405566	0.7679110	0.6538609	0.7566148	0.6669661	0.7450881	10
51	.6407799	.7677246	.6540810	.7564246	.6671828	.7448941	9
52	.6410032	.7675382	.6543010	.7562343	.6673994	.7446999	8
53	.6412264	.7673517	.6545209	.7560439	.6676160	.7445058	7
54	.6414496	.7671652	.6547408	.7558535	.6678326	.7443115	6
55	.6416728	.7669785	.6549607	.7556630	.6680490	.7441173	5
56	.6418958	.7667918	.6551804	.7554724	.6682655	.7439229	4
57	.6421189	.7666051	.6554002	.7552818	.6684818	.7437285	3
58	.6423418	.7664183	.6556198	.7550911	.6686981	.7435340	2
59	.6425647	.7662314	.6558395	.7549004	.6689144	.7433394	1
60	0.6427876	0.7660444	0.6560590	0.7547096	0.6691306	0.7431448	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	50°		49°		48°		

212 TABLE XXVII.—NATURAL SINES AND COSINES

	42°		43°		44°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	0.6691306	0.7431448	0.6819984	0.7313537	0.6946584	0.7193398	60
1	.6693468	.7429502	.6822111	.7311553	.6948676	.7191377	59
2	.6695628	.7427554	.6824237	.7309568	.6950767	.7189355	58
3	.6697789	.7425606	.6826363	.7307583	.6952858	.7187333	57
4	.6699948	.7423658	.6828489	.7305597	.6954949	.7185310	56
5	.6702108	.7421708	.6830613	.7303610	.6957039	.7183287	55
6	.6704266	.7419758	.6832738	.7301623	.6959128	.7181263	54
7	.6706424	.7417808	.6834861	.7299635	.6961217	.7179238	53
8	.6708582	.7415857	.6836984	.7297646	.6963305	.7177213	52
9	.6710739	.7413905	.6839107	.7295657	.6965392	.7175187	51
10	0.6712895	0.7411953	0.6841229	0.7293668	0.6967479	0.7173161	50
11	.6715051	.7410000	.6843350	.7291677	.6969565	.7171134	49
12	.6717206	.7408046	.6845471	.7289686	.6971651	.7169106	48
13	.6719361	.7406092	.6847591	.7287695	.6973736	.7167078	47
14	.6721515	.7404137	.6849711	.7285703	.6975821	.7165049	46
15	.6723668	.7402181	.6851830	.7283710	.6977905	.7163019	45
16	.6725821	.7400225	.6853948	.7281716	.6979988	.7160989	44
17	.6727973	.7398268	.6856066	.7279722	.6982071	.7158959	43
18	.6730125	.7396311	.6858184	.7277728	.6984153	.7156927	42
19	.6732276	.7394353	.6860300	.7275732	.6986234	.7154895	41
20	0.6734427	0.7392394	0.6862416	0.7273736	0.6988315	0.7152863	40
21	.6736577	.7390435	.6864532	.7271740	.6990396	.7150830	39
22	.6738727	.7388475	.6866647	.7269743	.6992476	.7148796	38
23	.6740876	.7386515	.6868761	.7267745	.6994555	.7146762	37
24	.6743024	.7384553	.6870875	.7265747	.6996633	.7144727	36
25	.6745172	.7382592	.6872988	.7263748	.6998711	.7142691	35
26	.6747319	.7380629	.6875101	.7261748	.7000789	.7140655	34
27	.6749466	.7378666	.6877213	.7259748	.7002866	.7138618	33
28	.6751612	.7376703	.6879325	.7257747	.7004942	.7136581	32
29	.6753757	.7374738	.6881435	.7255746	.7007018	.7134543	31
30	0.6755902	0.7372773	0.6883546	0.7253744	0.7009093	0.7132504	30
31	.6758046	.7370808	.6885655	.7251741	.7011167	.7130465	29
32	.6760190	.7368842	.6887765	.7249738	.7013241	.7128426	28
33	.6762333	.7366875	.6889873	.7247734	.7015314	.7126385	27
34	.6764476	.7364908	.6891981	.7245729	.7017387	.7124344	26
35	.6766618	.7362940	.6894089	.7243724	.7019459	.7122303	25
36	.6768760	.7360971	.6896195	.7241719	.7021531	.7120260	24
37	.6770901	.7359002	.6898302	.7239712	.7023601	.7118218	23
38	.6773041	.7357032	.6900407	.7237705	.7025672	.7116174	22
39	.6775181	.7355061	.6902512	.7235698	.7027741	.7114130	21
40	0.6777320	0.7353090	0.6904617	0.7233690	0.7029811	0.7112086	20
41	.6779459	.7351118	.6906721	.7231681	.7031879	.7110041	19
42	.6781597	.7349146	.6908824	.7229671	.7033947	.7107995	18
43	.6783734	.7347173	.6910927	.7227661	.7036014	.7105948	17
44	.6785871	.7345199	.6913029	.7225651	.7038081	.7103901	16
45	.6788007	.7343225	.6915131	.7223640	.7040147	.7101854	15
46	.6790143	.7341250	.6917232	.7221628	.7042213	.7099806	14
47	.6792278	.7339275	.6919332	.7219615	.7044278	.7097757	13
48	.6794413	.7337299	.6921432	.7217602	.7046342	.7095707	12
49	.6796547	.7335322	.6923531	.7215589	.7048406	.7093657	11
50	0.6798681	0.7333345	0.6925630	0.7213574	0.7050469	0.7091607	10
51	.6800813	.7331367	.6927728	.7211559	.7052532	.7089556	9
52	.6802946	.7329388	.6929825	.7209544	.7054594	.7087504	8
53	.6805078	.7327409	.6931922	.7207528	.7056655	.7085451	7
54	.6807209	.7325429	.6934018	.7205511	.7058716	.7083398	6
55	.6809339	.7323449	.6936114	.7203494	.7060776	.7081345	5
56	.6811469	.7321467	.6938209	.7201476	.7062835	.7079291	4
57	.6813599	.7319486	.6940304	.7199457	.7064894	.7077236	3
58	.6815728	.7317503	.6942398	.7197438	.7066953	.7075180	2
59	.6817856	.7315521	.6944491	.7195418	.7069011	.7073124	1
60	0.6819984	0.7313537	0.6946584	0.7193398	0.7071068	0.7071068	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	47°		46°		45°		

	0°		1°		2°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.0000000	Infinite	0.0174551	57.289962	0.0349208	28.636253	60
1	.0002909	3437.7467	.0177460	56.350590	.0352120	28.399397	59
2	.0005818	1718.8732	.0180370	55.441517	.0355033	28.166422	58
3	.0008727	1145.9153	.0183280	54.561300	.0357945	27.937233	57
4	.0011636	859.43630	.0186190	53.708588	.0360858	27.711740	56
5	.0014544	687.54887	.0189100	52.882109	.0363771	27.489853	55
6	.0017453	572.95721	.0192010	52.080673	.0366683	27.271486	54
7	.0020362	491.10600	.0194920	51.303157	.0369596	27.056557	53
8	.0023271	429.71757	.0197830	50.548506	.0372509	26.844984	52
9	.0026180	381.97099	.0200740	49.815726	.0375422	26.636690	51
10	0.0029089	343.77371	0.0203650	49.103881	0.0378335	26.431600	50
11	.0031998	312.52137	.0206560	48.412084	.0381248	26.229638	49
12	.0034907	286.47773	.0209470	47.739501	.0384161	26.030736	48
13	.0037816	264.44080	.0212380	47.085343	.0387074	25.834823	47
14	.0040725	245.55198	.0215291	46.448862	.0389988	25.641832	46
15	.0043634	229.18166	.0218201	45.829351	.0392901	25.451700	45
16	.0046542	214.85762	.0221111	45.226141	.0395814	25.264361	44
17	.0049451	202.21875	.0224021	44.638596	.0398728	25.079757	43
18	.0052360	190.98419	.0226932	44.066113	.0401641	24.897826	42
19	.0055269	180.93220	.0229842	43.508122	.0404555	24.718512	41
20	0.0058178	171.88540	0.0232753	42.964077	0.0407469	24.541758	40
21	.0061087	163.70019	.0235663	42.433464	.0410383	24.367509	39
22	.0063996	156.25908	.0238574	41.915790	.0413296	24.195714	38
23	.0066905	149.46502	.0241484	41.410588	.0416210	24.026320	37
24	.0069814	143.23712	.0244395	40.917412	.0419124	23.859277	36
25	.0072723	137.50745	.0247305	40.435837	.0422038	23.694537	35
26	.0075632	132.21851	.0250216	39.965461	.0424952	23.532052	34
27	.0078541	127.32134	.0253127	39.505895	.0427866	23.371777	33
28	.0081450	122.77396	.0256038	39.056771	.0430781	23.213666	32
29	.0084360	118.54018	.0258948	38.617738	.0433695	23.057677	31
30	0.0087269	114.58865	0.0261859	38.188459	0.0436609	22.903766	30
31	.0090178	110.89205	.0264770	37.768613	.0439524	22.751892	29
32	.0093087	107.42648	.0267681	37.357892	.0442438	22.602015	28
33	.0095996	104.17094	.0270592	36.956001	.0445353	22.454096	27
34	.0098905	101.10690	.0273503	36.562659	.0448268	22.308097	26
35	.0101814	98.217943	.0276414	36.177596	.0451183	22.163980	25
36	.0104724	95.489475	.0279325	35.800553	.0454097	22.021710	24
37	.0107633	92.908487	.0282236	35.431282	.0457012	21.881251	23
38	.0110542	90.463336	.0285148	35.069546	.0459927	21.742569	22
39	.0113451	88.143572	.0288059	34.715115	.0462842	21.605630	21
40	0.0116361	85.939791	0.0290970	34.367771	0.0465757	21.470401	20
41	.0119270	83.843507	.0293882	34.027303	.0468673	21.336851	19
42	.0122179	81.847041	.0296793	33.693509	.0471588	21.204949	18
43	.0125088	79.943430	.0299705	33.366194	.0474503	21.074664	17
44	.0127998	78.126342	.0302616	33.045173	.0477419	20.945966	16
45	.0130907	76.390009	.0305528	32.730264	.0480334	20.818828	15
46	.0133817	74.729165	.0308439	32.421295	.0483250	20.693220	14
47	.0136726	73.138991	.0311351	32.118099	.0486166	20.569115	13
48	.0139635	71.615070	.0314263	31.820516	.0489082	20.446486	12
49	.0142545	70.153346	.0317174	31.528392	.0491997	20.325308	11
50	0.0145454	68.750087	0.0320086	31.241577	0.0494913	20.205553	10
51	.0148364	67.401854	.0322998	30.959928	.0497829	20.087199	9
52	.0151273	66.105473	.0325910	30.683307	.0500746	19.970219	8
53	.0154183	64.858008	.0328822	30.411580	.0503662	19.854591	7
54	.0157093	63.656741	.0331734	30.144619	.0506578	19.740291	6
55	.0160002	62.499154	.0334646	29.882299	.0509495	19.627296	5
56	.0162912	61.382905	.0337558	29.624499	.0512411	19.515584	4
57	.0165821	60.305820	.0340471	29.371106	.0515328	19.405133	3
58	.0168731	59.265872	.0343383	29.122005	.0518244	19.295922	2
59	.0171641	58.261174	.0346295	28.877089	.0521161	19.187930	1
60	0.0174551	57.289962	0.0349208	28.636253	0.0524078	19.081137	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	89°		88°		87°		

	3°		4°		5°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.0524078	19.081137	0.0699268	14.300666	0.0874887	11.430052	60
1	.0526995	18.975523	.0702191	14.241134	.0877818	11.391885	59
2	.0529912	18.871068	.0705115	14.182092	.0880749	11.353970	58
3	.0532829	18.767754	.0708038	14.123536	.0883681	11.316304	57
4	.0535746	18.665562	.0710961	14.065459	.0886612	11.278885	56
5	.0538663	18.564473	.0713885	14.007856	.0889544	11.241712	55
6	.0541581	18.464471	.0716809	13.950719	.0892476	11.204780	54
7	.0544498	18.365537	.0719733	13.894045	.0895408	11.168089	53
8	.0547416	18.267654	.0722657	13.837827	.0898341	11.131635	52
9	.0550333	18.170807	.0725581	13.782060	.0901273	11.095416	51
10	0.0553251	18.074977	0.0728505	13.726738	0.0904206	11.059431	50
11	.0556169	17.980150	.0731430	13.671856	.0907138	11.023676	49
12	.0559087	17.886310	.0734354	13.617409	.0910071	10.988150	48
13	.0562005	17.793442	.0737279	13.563391	.0913004	10.952850	47
14	.0564923	17.701529	.0740203	13.509799	.0915938	10.917775	46
15	.0567841	17.610559	.0743128	13.456625	.0918871	10.882921	45
16	.0570759	17.520516	.0746053	13.403867	.0921804	10.848288	44
17	.0573678	17.431385	.0748979	13.351518	.0924738	10.813872	43
18	.0576596	17.343155	.0751904	13.299574	.0927672	10.779673	42
19	.0579515	17.255810	.0754829	13.248031	.0930606	10.745687	41
20	0.0582434	17.169337	0.0757755	13.196883	0.0933540	10.711913	40
21	.0585352	17.083724	.0760680	13.146127	.0936474	10.678348	39
22	.0588271	16.998957	.0763606	13.095757	.0939409	10.644992	38
23	.0591190	16.915025	.0766532	13.045769	.0942344	10.611841	37
24	.0594109	16.831915	.0769458	12.996160	.0945278	10.578895	36
25	.0597029	16.749614	.0772384	12.946924	.0948213	10.546151	35
26	.0599948	16.668112	.0775311	12.898058	.0951148	10.513607	34
27	.0602867	16.587396	.0778237	12.849557	.0954084	10.481261	33
28	.0605787	16.507456	.0781164	12.801417	.0957019	10.449112	32
29	.0608706	16.428279	.0784090	12.753634	.0959955	10.417158	31
30	0.0611626	16.349855	0.0787017	12.706205	0.0962890	10.385397	30
31	.0614546	16.272174	.0789944	12.659125	.0965826	10.353827	29
32	.0617466	16.195225	.0792871	12.612390	.0968763	10.322447	28
33	.0620386	16.118998	.0795798	12.565997	.0971699	10.291255	27
34	.0623306	16.043482	.0798726	12.519942	.0974635	10.260249	26
35	.0626226	15.968667	.0801653	12.474221	.0977572	10.229428	25
36	.0629147	15.894545	.0804581	12.428831	.0980509	10.198789	24
37	.0632067	15.821105	.0807509	12.383768	.0983446	10.168332	23
38	.0634988	15.748337	.0810437	12.339028	.0986383	10.138054	22
39	.0637908	15.676233	.0813365	12.294609	.0989320	10.107954	21
40	0.0640829	15.604784	0.0816293	12.250505	0.0992257	10.078031	20
41	.0643750	15.533981	.0819221	12.206716	.0995195	10.048283	19
42	.0646671	15.463814	.0822150	12.163236	.0998133	10.018708	18
43	.0649592	15.394276	.0825078	12.120062	.1001071	9.9893050	17
44	.0652513	15.325358	.0828007	12.077192	.1004009	9.9600724	16
45	.0655435	15.257052	.0830936	12.034622	.1006947	9.9310088	15
46	.0658356	15.189349	.0833865	11.992349	.1009886	9.9021125	14
47	.0661278	15.122242	.0836794	11.950371	.1012824	9.8733823	13
48	.0664199	15.055723	.0839723	11.908682	.1015763	9.8448166	12
49	.0667121	14.989784	.0842653	11.867282	.1018702	9.8164140	11
50	0.0670043	14.924417	0.0845583	11.826167	0.1021641	9.7881732	10
51	.0672965	14.859616	.0848512	11.785333	.1024580	9.7600927	9
52	.0675887	14.795372	.0851442	11.744779	.1027520	9.7321713	8
53	.0678809	14.731679	.0854372	11.704500	.1030460	9.7044075	7
54	.0681732	14.668529	.0857302	11.664495	.1033400	9.6768000	6
55	.0684654	14.605916	.0860233	11.624761	.1036340	9.6493475	5
56	.0687577	14.543833	.0863163	11.585294	.1039280	9.6220486	4
57	.0690499	14.482273	.0866094	11.546093	.1042220	9.5949022	3
58	.0693422	14.421230	.0869025	11.507154	.1045161	9.5679068	2
59	.0696345	14.360696	.0871956	11.468474	.1048101	9.5410613	1
60	0.0699268	14.300666	0.0874887	11.430052	0.1051042	9.5143645	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	86°		85°		84°		

	6°		7°		8°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.1051042	9.5143645	0.1227846	8.1443464	0.1405408	7.1153697	60
1	.1053983	9.4878149	.1230798	8.1248071	.1408375	7.1003826	59
2	.1056925	9.4614116	.1233752	8.1053599	.1411342	7.0854573	58
3	.1059866	9.4351531	.1236705	8.0860042	.1414308	7.0705934	57
4	.1062808	9.4090384	.1239658	8.0667394	.1417276	7.0557905	56
5	.1065750	9.3830663	.1242612	8.0475647	.1420243	7.0410482	55
6	.1068692	9.3572355	.1245566	8.0284796	.1423211	7.0263662	54
7	.1071634	9.3315450	.1248520	8.0094835	.1426179	7.0117441	53
8	.1074576	9.3059936	.1251474	7.9905756	.1429147	6.9971816	52
9	.1077519	9.2805802	.1254429	7.9717555	.1432115	6.9826781	51
10	0.1080462	9.2553035	0.1257384	7.9530224	0.1435084	6.9682335	50
11	.1083405	9.2301627	.1260339	7.9343758	.1438053	6.9538473	49
12	.1086348	9.2051564	.1263294	7.9158151	.1441022	6.9395192	48
13	.1089291	9.1802838	.1266249	7.8973396	.1443991	6.9252489	47
14	.1092234	9.1555436	.1269205	7.8789489	.1446961	6.9110359	46
15	.1095178	9.1309348	.1272161	7.8606423	.1449931	6.8968799	45
16	.1098122	9.1064564	.1275117	7.8424191	.1452901	6.8827807	44
17	.1101066	9.0821074	.1278073	7.8242790	.1455872	6.8687378	43
18	.1104010	9.0578867	.1281030	7.8062212	.1458842	6.8547508	42
19	.1106955	9.0337933	.1283986	7.7882453	.1461813	6.8408196	41
20	0.1109899	9.0098261	0.1286943	7.7703506	0.1464784	6.8269437	40
21	.1112844	8.9859843	.1289900	7.7525366	.1467756	6.8131227	39
22	.1115789	8.9622668	.1292858	7.7348028	.1470727	6.7993565	38
23	.1118734	8.9386726	.1295815	7.7171486	.1473699	6.7856446	37
24	.1121680	8.9152009	.1298773	7.6995735	.1476672	6.7719867	36
25	.1124625	8.8918505	.1301731	7.6820769	.1479644	6.7583826	35
26	.1127571	8.8686206	.1304690	7.6646584	.1482617	6.7448318	34
27	.1130517	8.8455103	.1307648	7.6473174	.1485590	6.7313341	33
28	.1133463	8.8225186	.1310607	7.6300533	.1488563	6.7178891	32
29	.1136410	8.7996446	.1313566	7.6128657	.1491536	6.7044966	31
30	0.1139356	8.7768874	0.1316525	7.5957541	0.1494510	6.6911562	30
31	.1142303	8.7542461	.1319484	7.5787179	.1497484	6.6778677	29
32	.1145250	8.7317198	.1322444	7.5617567	.1500458	6.6646307	28
33	.1148197	8.7093077	.1325404	7.5448699	.1503433	6.6514449	27
34	.1151144	8.6870088	.1328364	7.5280571	.1506408	6.6383100	26
35	.1154092	8.6648223	.1331324	7.5113178	.1509383	6.6252258	25
36	.1157039	8.6427475	.1334285	7.4946514	.1512358	6.6121919	24
37	.1159987	8.6207833	.1337246	7.4780576	.1515333	6.5992080	23
38	.1162936	8.5989290	.1340207	7.4615357	.1518309	6.5862739	22
39	.1165884	8.5771838	.1343168	7.4450855	.1521285	6.5733892	21
40	0.1168832	8.5555468	0.1346129	7.4287064	0.1524262	6.5605538	20
41	.1171781	8.5340172	.1349091	7.4123978	.1527238	6.5477672	19
42	.1174730	8.5125943	.1352053	7.3961595	.1530215	6.5350293	18
43	.1177679	8.4912772	.1355015	7.3799909	.1533192	6.5223396	17
44	.1180628	8.4700651	.1357978	7.3638916	.1536170	6.5096981	16
45	.1183578	8.4489573	.1360940	7.3478610	.1539147	6.4971043	15
46	.1186528	8.4279531	.1363903	7.3318989	.1542125	6.4845581	14
47	.1189478	8.4070511	.1366866	7.3160047	.1545103	6.4720591	13
48	.1192428	8.3862519	.1369830	7.3001780	.1548082	6.4596070	12
49	.1195378	8.3655536	.1372793	7.2844184	.1551061	6.4472017	11
50	0.1198329	8.3449558	0.1375757	7.2687255	0.1554040	6.4348428	10
51	.1201279	8.3244577	.1378721	7.2530987	.1557019	6.4225301	9
52	.1204230	8.3040586	.1381685	7.2375378	.1559998	6.4102633	8
53	.1207182	8.2837579	.1384650	7.2220422	.1562978	6.3980422	7
54	.1210133	8.2635547	.1387615	7.2066116	.1565958	6.3858665	6
55	.1213085	8.2434485	.1390580	7.1912456	.1568939	6.3737359	5
56	.1216036	8.2234384	.1393545	7.1759437	.1571919	6.3616502	4
57	.1218988	8.2035239	.1396510	7.1607056	.1574900	6.3496092	3
58	.1221941	8.1837041	.1399476	7.1455308	.1577881	6.3376126	2
59	.1224893	8.1639786	.1402442	7.1304190	.1580863	6.3256601	1
60	0.1227846	8.1443464	0.1405408	7.1153697	0.1583844	6.3137515	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
83°		82°		81°			

	9°		10°		11°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.1583844	6.3137515	0.1763270	5.6712818	0.1943803	5.1445540	60
1	.1586826	6.3018866	.1766269	5.6616509	.1946822	5.1365763	59
2	.1589809	6.2900651	.1769269	5.6520516	.1949841	5.1286224	58
3	.1592791	6.2782868	.1772269	5.6424838	.1952861	5.1206921	57
4	.1595774	6.2665515	.1775270	5.6329474	.1955881	5.1127855	56
5	.1598757	6.2548588	.1778270	5.6234421	.1958901	5.1049024	55
6	.1601740	6.2432086	.1781271	5.6139680	.1961922	5.0970426	54
7	.1604724	6.2316007	.1784273	5.6045247	.1964943	5.0892061	53
8	.1607708	6.2200347	.1787274	5.5951121	.1967964	5.0813928	52
9	.1610692	6.2085106	.1790276	5.5857302	.1970986	5.0736025	51
10	0.1613677	6.1970279	0.1793279	5.5763786	0.1974008	5.0658352	50
11	.1616662	6.1855867	.1796281	5.5670574	.1977031	5.0580907	49
12	.1619647	6.1741865	.1799284	5.5577663	.1980053	5.0503690	48
13	.1622632	6.1628272	.1802287	5.5485052	.1983076	5.0426700	47
14	.1625618	6.1515085	.1805291	5.5392740	.1986100	5.0349935	46
15	.1628603	6.1402303	.1808295	5.5300724	.1989124	5.0273395	45
16	.1631590	6.1289923	.1811299	5.5209005	.1992148	5.0197078	44
17	.1634576	6.1177943	.1814303	5.5117579	.1995172	5.0120984	43
18	.1637563	6.1066360	.1817308	5.5026446	.1998197	5.0045111	42
19	.1640550	6.0955174	.1820313	5.4935604	.2001222	4.9969459	41
20	0.1643537	6.0844381	0.1823319	5.4845052	0.2004248	4.9894027	40
21	.1646525	6.0733979	.1826324	5.4754788	.2007274	4.9818813	39
22	.1649513	6.0623967	.1829330	5.4664812	.2010300	4.9743817	38
23	.1652501	6.0514343	.1832337	5.4575121	.2013327	4.9669037	37
24	.1655489	6.0405103	.1835343	5.4485715	.2016354	4.9594474	36
25	.1658478	6.0296247	.1838350	5.4396592	.2019381	4.9520125	35
26	.1661467	6.0187772	.1841358	5.4307750	.2022409	4.9445990	34
27	.1664456	6.0079676	.1844365	5.4219188	.2025437	4.9372068	33
28	.1667446	5.9971957	.1847373	5.4130906	.2028465	4.9298358	32
29	.1670436	5.9864614	.1850382	5.4042901	.2031494	4.9224859	31
30	0.1673426	5.9757644	0.1853390	5.3955172	0.2034523	4.9151570	30
31	.1676417	5.9651045	.1856399	5.3867718	.2037552	4.9078491	29
32	.1679407	5.9544815	.1859409	5.3780538	.2040582	4.9005620	28
33	.1682398	5.9438952	.1862418	5.3693630	.2043612	4.8932956	27
34	.1685390	5.9333455	.1865428	5.3606993	.2046643	4.8860499	26
35	.1688381	5.9228322	.1868439	5.3520626	.2049674	4.8788248	25
36	.1691373	5.9123550	.1871449	5.3434527	.2052705	4.8716201	24
37	.1694366	5.9019138	.1874460	5.3348696	.2055737	4.8644359	23
38	.1697358	5.8915084	.1877471	5.3263131	.2058769	4.8572719	22
39	.1700351	5.8811386	.1880483	5.3177830	.2061802	4.8501282	21
40	0.1703344	5.8708042	0.1883495	5.3092793	0.2064834	4.8430045	20
41	.1706338	5.8605051	.1886507	5.3008018	.2067867	4.8359010	19
42	.1709331	5.8502410	.1889520	5.2923505	.2070900	4.8288174	18
43	.1712325	5.8400117	.1892533	5.2839251	.2073934	4.8217536	17
44	.1715320	5.8298172	.1895546	5.2755255	.2076968	4.8147096	16
45	.1718314	5.8196572	.1898559	5.2671517	.2080003	4.8076854	15
46	.1721309	5.8095315	.1901573	5.2588035	.2083038	4.8006808	14
47	.1724304	5.7994400	.1904587	5.2504809	.2086073	4.7936957	13
48	.1727300	5.7893825	.1907602	5.2421836	.2089109	4.7867300	12
49	.1730296	5.7793588	.1910617	5.2339116	.2092145	4.7797837	11
50	0.1733292	5.7693688	0.1913632	5.2256647	0.2095181	4.7728568	10
51	.1736288	5.7594122	.1916648	5.2174428	.2098218	4.7659490	9
52	.1739285	5.7494889	.1919664	5.2092459	.2101255	4.7590603	8
53	.1742282	5.7395988	.1922680	5.2010738	.2104293	4.7521907	7
54	.1745279	5.7297416	.1925696	5.1929264	.2107331	4.7453401	6
55	.1748277	5.7199173	.1928713	5.1848035	.2110369	4.7385083	5
56	.1751275	5.7101256	.1931731	5.1767051	.2113407	4.7316954	4
57	.1754273	5.7003663	.1934748	5.1686311	.2116446	4.7249012	3
58	.1757272	5.6906394	.1937766	5.1605813	.2119486	4.7181256	2
59	.1760271	5.6809446	.1940784	5.1525557	.2122525	4.7113686	1
60	0.1763270	5.6712818	0.1943803	5.1445540	0.2125566	4.7046301	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	80°		79°		78°		

12°		13°		14°		
Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	.2125566	4.7046301	0.2308682	4.3314759	0.2493280	4.0107809 60
1	.2128606	4.6979100	.2311746	4.3257347	.2496370	4.0058164 59
2	.2131647	4.6912083	.2314811	4.3200079	.2499460	4.0008636 58
3	.2134688	4.6845248	.2317876	4.3142955	.2502551	3.9959223 57
4	.2137730	4.6778595	.2320941	4.3085974	.2505642	3.9909924 56
5	.2140772	4.6712124	.2324007	4.3029136	.2508734	3.9860739 55
6	.2143814	4.6645832	.2327073	4.2972440	.2511826	3.9811669 54
7	.2146857	4.6579721	.2330140	4.2915885	.2514919	3.9762712 53
8	.2149900	4.6513788	.2333207	4.2859472	.2518012	3.9713868 52
9	.2152944	4.6448034	.2336274	4.2803199	.2521106	3.9665137 51
10	0.2155988	4.6382457	0.2339342	4.2747066	0.2524200	3.9616518 50
11	.2159032	4.6317056	.2342411	4.2691072	.2527294	3.9568011 49
12	.2162077	4.6251832	.2345479	4.2635218	.2530389	3.9519615 48
13	.2165122	4.6186783	.2348548	4.2579501	.2533484	3.9471331 47
14	.2168167	4.6121908	.2351617	4.2523923	.2536580	3.9423157 46
15	.2171213	4.6057207	.2354687	4.2468482	.2539676	3.9375094 45
16	.2174259	4.5992680	.2357758	4.2413177	.2542773	3.9327141 44
17	.2177306	4.5928325	.2360829	4.2358009	.2545870	3.9279297 43
18	.2180353	4.5864141	.2363900	4.2302977	.2548968	3.9231563 42
19	.2183400	4.5800129	.2366971	4.2248080	.2552066	3.9183937 41
20	0.2186448	4.5736287	0.2370044	4.2193318	0.2555165	3.9136420 40
21	.2189496	4.5672615	.2373116	4.2138690	.2558264	3.9089011 39
22	.2192544	4.5609111	.2376189	4.2084196	.2561363	3.9041710 38
23	.2195593	4.5545776	.2379262	4.2029835	.2564463	3.8994516 37
24	.2198643	4.5482608	.2382336	4.1975606	.2567564	3.8947429 36
25	.2201692	4.5419608	.2385410	4.1921510	.2570664	3.8900448 35
26	.2204742	4.5356773	.2388485	4.1867546	.2573766	3.8853574 34
27	.2207793	4.5294105	.2391560	4.1813713	.2576868	3.8806805 33
28	.2210844	4.5231601	.2394635	4.1760011	.2579970	3.8760142 32
29	.2213895	4.5169261	.2397711	4.1706440	.2583073	3.8713584 31
30	0.2216947	4.5107085	0.2400788	4.1652998	0.2586176	3.8667131 30
31	.2219999	4.5045072	.2403864	4.1599685	.2589280	3.8620782 29
32	.2223051	4.4983221	.2406942	4.1546501	.2592384	3.8574537 28
33	.2226104	4.4921532	.2410019	4.1493446	.2595488	3.8528396 27
34	.2229157	4.4860004	.2413097	4.1440519	.2598593	3.8482358 26
35	.2232211	4.4798636	.2416176	4.1387719	.2601699	3.8436424 25
36	.2235265	4.4737428	.2419255	4.1335046	.2604805	3.8390591 24
37	.2238319	4.4676379	.2422334	4.1282499	.2607911	3.8344861 23
38	.2241374	4.4615489	.2425414	4.1230079	.2611018	3.8299233 22
39	.2244429	4.4554756	.2428494	4.1177784	.2614126	3.8253707 21
40	0.2247485	4.4494181	0.2431575	4.1125614	0.2617234	3.8208281 20
41	.2250541	4.4433762	.2434656	4.1073569	.2620342	3.8162957 19
42	.2253597	4.4373500	.2437737	4.1021649	.2623451	3.8117733 18
43	.2256654	4.4313392	.2440819	4.0969852	.2626560	3.8072609 17
44	.2259711	4.4253439	.2443902	4.0918178	.2629670	3.8027585 16
45	.2262769	4.4193641	.2446984	4.0866627	.2632780	3.7982661 15
46	.2265827	4.4133996	.2450068	4.0815199	.2635891	3.7937835 14
47	.2268885	4.4074504	.2453151	4.0763892	.2639002	3.7893109 13
48	.2271944	4.4015164	.2456236	4.0712707	.2642114	3.7848481 12
49	.2275003	4.3955977	.2459320	4.0661643	.2645226	3.7803951 11
50	0.2278063	4.3896940	0.2462405	4.0610700	0.2648339	3.7759519 10
51	.2281123	4.3838054	.2465491	4.0559877	.2651452	3.7715185 9
52	.2284184	4.3779317	.2468577	4.0509174	.2654566	3.7670947 8
53	.2287244	4.3720731	.2471663	4.0458590	.2657680	3.7626807 7
54	.2290306	4.3662293	.2474750	4.0408125	.2660794	3.7582763 6
55	.2293367	4.3604003	.2477837	4.0357779	.2663909	3.7538815 5
56	.2296429	4.3545861	.2480925	4.0307550	.2667025	3.7494963 4
57	.2299492	4.3487866	.2484013	4.0257440	.2670141	3.7451207 3
58	.2302555	4.3430018	.2487102	4.0207446	.2673257	3.7407546 2
59	.2305618	4.3372316	.2490191	4.0157570	.2676374	3.7363980 1
60	0.2308682	4.3314759	0.2493280	4.0107809	0.2679492	3.7320508 0
Cotangent		Cotangent		Cotangent		
Tangent		Tangent		Tangent		
77°		76°		75°		

	15°		16°		17°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.2679492	3.7320508	0.2867454	3.4874144	0.3057307	3.2708526	60
1	.2682610	3.7277131	.2870602	3.4835896	.3060488	3.2674529	59
2	.2685728	3.7233847	.2873751	3.4797726	.3063670	3.2640596	58
3	.2688847	3.7190658	.2876900	3.4759632	.3066852	3.2606728	57
4	.2691967	3.7147561	.2880050	3.4721616	.3070034	3.2572924	56
5	.2695087	3.7104558	.2883201	3.4683676	.3073218	3.2539184	55
6	.2698207	3.7061648	.2886352	3.4645813	.3076402	3.2505508	54
7	.2701328	3.7018830	.2889503	3.4608026	.3079586	3.2471895	53
8	.2704449	3.6976104	.2892655	3.4570315	.3082771	3.2438346	52
9	.2707571	3.6933469	.2895808	3.4532679	.3085957	3.2404861	51
10	0.2710694	3.6890927	0.2898961	3.4495120	0.3089143	3.2371438	50
11	.2713817	3.6848475	.2902114	3.4457635	.3092330	3.2338078	49
12	.2716940	3.6806115	.2905269	3.4420226	.3095517	3.2304780	48
13	.2720064	3.6763845	.2908423	3.4382891	.3098705	3.2271546	47
14	.2723188	3.6721665	.2911578	3.4345631	.3101893	3.2238373	46
15	.2726313	3.6679575	.2914734	3.4308446	.3105083	3.2205263	45
16	.2729438	3.6637575	.2917890	3.4271334	.3108272	3.2172215	44
17	.2732564	3.6595665	.2921047	3.4234297	.3111462	3.2139228	43
18	.2735690	3.6553844	.2924205	3.4197333	.3114653	3.2106304	42
19	.2738817	3.6512111	.2927363	3.4160443	.3117845	3.2073140	41
20	0.2741945	3.6470467	0.2930521	3.4123626	0.3121036	3.2040638	40
21	.2745072	3.6428911	.2933680	3.4086882	.3124229	3.2007897	39
22	.2748201	3.6387444	.2936839	3.4050210	.3127422	3.1975217	38
23	.2751330	3.6346064	.2939999	3.4013612	.3130616	3.1942597	37
24	.2754459	3.6304771	.2943160	3.3977085	.3133810	3.1910039	36
25	.2757589	3.6263566	.2946321	3.3940631	.3137005	3.1877540	35
26	.2760719	3.6222447	.2949483	3.3904249	.3140200	3.1845102	34
27	.2763850	3.6181415	.2952645	3.3867938	.3143396	3.1812724	33
28	.2766981	3.6140469	.2955808	3.3831699	.3146593	3.1780406	32
29	.2770113	3.6099609	.2958971	3.3795531	.3149790	3.1748147	31
30	0.2773245	3.6058835	0.2962135	3.3759434	0.3152988	3.1715948	30
31	.2776378	3.6018146	.2965299	3.3723408	.3156186	3.1683808	29
32	.2779512	3.5977543	.2968464	3.3687453	.3159385	3.1651728	28
33	.2782646	3.5937024	.2971630	3.3651568	.3162585	3.1619706	27
34	.2785780	3.5896590	.2974796	3.3615753	.3165785	3.1587744	26
35	.2788915	3.5856241	.2977962	3.3580008	.3168986	3.1555840	25
36	.2792050	3.5815975	.2981129	3.3544333	.3172187	3.1523994	24
37	.2795186	3.5775794	.2984297	3.3508728	.3175389	3.1492207	23
38	.2798322	3.5735696	.2987465	3.3473191	.3178591	3.1460478	22
39	.2801459	3.5695681	.2990634	3.3437724	.3181794	3.1428807	21
40	0.2804597	3.5655749	0.2993803	3.3402326	0.3184998	3.1397194	20
41	.2807735	3.5615900	.2996973	3.3366997	.3188202	3.1365639	19
42	.2810873	3.5576133	.3000144	3.3331736	.3191407	3.1334141	18
43	.2814012	3.5536449	.3003315	3.3296543	.3194613	3.1302701	17
44	.2817152	3.5496846	.3006486	3.3261419	.3197819	3.1271317	16
45	.2820292	3.5457325	.3009658	3.3226362	.3201025	3.1239991	15
46	.2823432	3.5417886	.3012831	3.3191373	.3204232	3.1208722	14
47	.2826573	3.5378528	.3016004	3.3156452	.3207440	3.1177509	13
48	.2829715	3.5339251	.3019178	3.3121598	.3210649	3.1146353	12
49	.2832857	3.5300054	.3022352	3.3086811	.3213858	3.1115254	11
50	0.2835999	3.5260938	0.3025527	3.3052091	0.3217067	3.1084210	10
51	.2839143	3.5221902	.3028703	3.3017438	.3220278	3.1053223	9
52	.2842286	3.5182946	.3031879	3.2982851	.3223489	3.1022291	8
53	.2845430	3.5144070	.3035055	3.2948330	.3226700	3.0991416	7
54	.2848575	3.5105273	.3038232	3.2913876	.3229912	3.0960596	6
55	.2851720	3.5066555	.3041410	3.2879487	.3233125	3.0929831	5
56	.2854866	3.5027916	.3044588	3.2845164	.3236338	3.0899122	4
57	.2858012	3.4989356	.3047767	3.2810907	.3239552	3.0868468	3
58	.2861159	3.4950874	.3050946	3.2776715	.3242766	3.0837869	2
59	.2864306	3.4912470	.3054126	3.2742588	.3245981	3.0807325	1
60	0.2867454	3.4874144	0.3057307	3.2708526	0.3249197	3.0776835	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	74°		73°		72°		

	18°		19°		20°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.3249197	3.0776835	0.3443276	2.9042109	0.3639702	2.7474774	60
1	.3252413	3.0746400	.3446530	2.9014688	.3642997	2.7449927	59
2	.3255630	3.0716020	.3449785	2.8987314	.3646292	2.7425120	58
3	.3258848	3.0685694	.3453040	2.8959986	.3649588	2.7400352	57
4	.3262066	3.0655421	.3456296	2.8932704	.3652885	2.7375623	56
5	.3265284	3.0625203	.3459553	2.8905467	.3656182	2.7350934	55
6	.3268504	3.0595038	.3462810	2.8878277	.3659480	2.7326284	54
7	.3271724	3.0564928	.3466068	2.8851132	.3662779	2.7301674	53
8	.3274944	3.0534870	.3469327	2.8824033	.3666079	2.7277102	52
9	.3278165	3.0504866	.3472586	2.8796979	.3669379	2.7252569	51
10	0.3281387	3.0474915	0.3475846	2.8769970	0.3672680	2.7228076	50
11	.3284610	3.0445018	.3479107	2.8743007	.3675981	2.7203620	49
12	.3287833	3.0415173	.3482368	2.8716088	.3679284	2.7179204	48
13	.3291056	3.0385381	.3485630	2.8689215	.3682587	2.7154826	47
14	.3294281	3.0355641	.3488893	2.8662386	.3685890	2.7130487	46
15	.3297505	3.0325954	.3492156	2.8635602	.3689195	2.7106186	45
16	.3300731	3.0296320	.3495420	2.8608863	.3692500	2.7081923	44
17	.3303957	3.0266737	.3498685	2.8582168	.3695806	2.7057699	43
18	.3307184	3.0237207	.3501950	2.8555517	.3699112	2.7033513	42
19	.3310411	3.0207728	.3505216	2.8528911	.3702420	2.7009364	41
20	0.3313639	3.0178301	0.3508483	2.8502349	0.3705728	2.6985254	40
21	.3316868	3.0148926	.3511750	2.8475831	.3709036	2.6961181	39
22	.3320097	3.0119603	.3515018	2.8449356	.3712346	2.6937147	38
23	.3323327	3.0090330	.3518287	2.8422926	.3715656	2.6913149	37
24	.3326557	3.0061109	.3521556	2.8396539	.3718967	2.6889190	36
25	.3329788	3.0031939	.3524826	2.8370196	.3722278	2.6865267	35
26	.3333020	3.0002820	.3528096	2.8343896	.3725590	2.6841383	34
27	.3336252	2.9973751	.3531368	2.8317640	.3728903	2.6817535	33
28	.3339485	2.9944734	.3534640	2.8291426	.3732217	2.6793725	32
29	.3342719	2.9915766	.3537912	2.8265256	.3735532	2.6769951	31
30	0.3345953	2.9886850	0.3541186	2.8239129	0.3738847	2.6746215	30
31	.3349188	2.9857983	.3544460	2.8213045	.3742163	2.6722516	29
32	.3352424	2.9829167	.3547734	2.8187003	.3745479	2.6698853	28
33	.3355660	2.9800400	.3551010	2.8161004	.3748797	2.6675227	27
34	.3358896	2.9771683	.3554286	2.8135048	.3752115	2.6651638	26
35	.3362134	2.9743016	.3557562	2.8109134	.3755433	2.6628085	25
36	.3365372	2.9714399	.3560840	2.8083263	.3758753	2.6604569	24
37	.3368610	2.9685831	.3564118	2.8057433	.3762073	2.6581089	23
38	.3371850	2.9657312	.3567397	2.8031646	.3765394	2.6557645	22
39	.3375090	2.9628842	.3570676	2.8005901	.3768716	2.6534238	21
40	0.3378330	2.9600422	0.3573956	2.7980198	0.3772038	2.6510867	20
41	.3381571	2.9572050	.3577237	2.7954537	.3775361	2.6487531	19
42	.3384813	2.9543727	.3580518	2.7928917	.3778685	2.6464232	18
43	.3388056	2.9515453	.3583801	2.7903339	.3782010	2.6440969	17
44	.3391299	2.9487227	.3587083	2.7877802	.3785335	2.6417741	16
45	.3394543	2.9459050	.3590367	2.7852307	.3788661	2.6394549	15
46	.3397787	2.9430921	.3593651	2.7826853	.3791988	2.6371392	14
47	.3401032	2.9402840	.3596936	2.7801440	.3795315	2.6348271	13
48	.3404278	2.9374807	.3600222	2.7776069	.3798644	2.6325186	12
49	.3407524	2.9346822	.3603508	2.7750738	.3801973	2.6302136	11
50	0.3410771	2.9318885	0.3606795	2.7725448	0.3805302	2.6279121	10
51	.3414019	2.9290995	.3610082	2.7700199	.3808633	2.6256141	9
52	.3417267	2.9263152	.3613371	2.7674991	.3811964	2.6233196	8
53	.3420516	2.9235358	.3616660	2.7649822	.3815296	2.6210286	7
54	.3423765	2.9207610	.3619949	2.7624695	.3818629	2.6187411	6
55	.3427015	2.9179909	.3623240	2.7599608	.3821962	2.6164571	5
56	.3430266	2.9152256	.3626531	2.7574561	.3825296	2.6141766	4
57	.3433518	2.9124649	.3629823	2.7549554	.3828631	2.6118995	3
58	.3436770	2.9097089	.3633115	2.7524588	.3831967	2.6096259	2
59	.3440023	2.9069576	.3636408	2.7499661	.3835303	2.6073558	1
60	0.3443276	2.9042109	0.3639702	2.7474774	0.3838640	2.6050891	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	71°		70°		69°		

	21°		22°		23°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.3838640	2.6050891	0.4040262	2.4750869	0.4244748	2.3558524	60
1	.3841978	2.6028258	.4043646	2.4730155	.4248182	2.3539483	59
2	.3845317	2.6005695	.4047031	2.4709470	.4251616	2.3520469	58
3	.3848656	2.5983095	.4050417	2.4688816	.4255051	2.3501481	57
4	.3851996	2.5960564	.4053804	2.4668191	.4258487	2.3482519	56
5	.3855337	2.5938068	.4057191	2.4647596	.4261924	2.3463582	55
6	.3858679	2.5915606	.4060579	2.4627030	.4265361	2.3444672	54
7	.3862021	2.5893177	.4063968	2.4606494	.4268800	2.3425787	53
8	.3865364	2.5870782	.4067358	2.4585987	.4272239	2.3406928	52
9	.3868708	2.5848421	.4070748	2.4565510	.4275680	2.3388095	51
10	0.3872053	2.5826094	0.4074139	2.4545061	0.4279121	2.3369287	50
11	.3875398	2.5803800	.4077531	2.4524642	.4282563	2.3350505	49
12	.3878744	2.5781539	.4080924	2.4504252	.4286005	2.3331748	48
13	.3882091	2.5759312	.4084318	2.4483891	.4289449	2.3313017	47
14	.3885439	2.5737118	.4087713	2.4463559	.4292894	2.3294311	46
15	.3888787	2.5714957	.4091108	2.4443256	.4296339	2.3275630	45
16	.3892136	2.5692830	.4094504	2.4422982	.4299785	2.3256975	44
17	.3895486	2.5670735	.4097901	2.4402736	.4303232	2.3238345	43
18	.3898837	2.5648674	.4101299	2.4382519	.4306680	2.3219740	42
19	.3902189	2.5626645	.4104697	2.4362331	.4310129	2.3201160	41
20	0.3905541	2.5604649	0.4108097	2.4342172	0.4313579	2.3182606	40
21	.3908894	2.5582686	.4111497	2.4322041	.4317030	2.3164076	39
22	.3912247	2.5560756	.4114898	2.4301938	.4320481	2.3145571	38
23	.3915602	2.5538858	.4118300	2.4281864	.4323933	2.3127092	37
24	.3918957	2.5516992	.4121703	2.4261819	.4327386	2.3108637	36
25	.3922313	2.5495160	.4125106	2.4241801	.4330840	2.3090206	35
26	.3925670	2.5473359	.4128510	2.4221812	.4334295	2.3071801	34
27	.3929027	2.5451591	.4131915	2.4201851	.4337751	2.3053420	33
28	.3932386	2.5429855	.4135321	2.4181918	.4341208	2.3035064	32
29	.3935745	2.5408151	.4138728	2.4162013	.4344665	2.3016732	31
30	0.3939105	2.5386479	0.4142136	2.4142136	0.4348124	2.2998425	30
31	.3942465	2.5364839	.4145544	2.4122286	.4351583	2.2980143	29
32	.3945827	2.5343231	.4148953	2.4102465	.4355043	2.2961885	28
33	.3949189	2.5321655	.4152363	2.4082672	.4358504	2.2943651	27
34	.3952552	2.5300111	.4155774	2.4062906	.4361966	2.2925442	26
35	.3955916	2.5278598	.4159186	2.4043168	.4365429	2.2907257	25
36	.3959280	2.5257117	.4162598	2.4023457	.4368893	2.2889096	24
37	.3962645	2.5235667	.4166012	2.4003774	.4372357	2.2870959	23
38	.3966011	2.5214249	.4169426	2.3984118	.4375823	2.2852846	22
39	.3969378	2.5192863	.4172841	2.3964490	.4379289	2.2834758	21
40	0.3972746	2.5171507	0.4176257	2.3944889	0.4382756	2.2816693	20
41	.3976114	2.5150183	.4179673	2.3925316	.4386224	2.2798653	19
42	.3979483	2.5128890	.4183091	2.3905769	.4389693	2.2780636	18
43	.3982853	2.5107629	.4186509	2.3886250	.4393163	2.2762643	17
44	.3986224	2.5086398	.4189928	2.3866758	.4396634	2.2744674	16
45	.3989595	2.5065198	.4193348	2.3847293	.4400105	2.2726729	15
46	.3992968	2.5044029	.4196769	2.3827855	.4403578	2.2708807	14
47	.3996341	2.5022891	.4200190	2.3808444	.4407051	2.2690909	13
48	.3999715	2.5001784	.4203613	2.3789060	.4410526	2.2673035	12
49	.4003089	2.4980707	.4207036	2.3769703	.4414001	2.2655184	11
50	0.4006465	2.4959661	0.4210460	2.3750372	0.4417477	2.2637357	10
51	.4009841	2.4938645	.4213885	2.3731068	.4420954	2.2619554	9
52	.4013218	2.4917660	.4217311	2.3711791	.4424432	2.2601773	8
53	.4016596	2.4896706	.4220738	2.3692540	.4427910	2.2584016	7
54	.4019974	2.4875781	.4224165	2.3673316	.4431390	2.2566283	6
55	.4023354	2.4854887	.4227594	2.3654118	.4434871	2.2548572	5
56	.4026734	2.4834023	.4231023	2.3634946	.4438352	2.2530885	4
57	.4030115	2.4813190	.4234453	2.3615801	.4441834	2.2513221	3
58	.4033496	2.4792386	.4237884	2.3596683	.4445318	2.2495580	2
59	.4036879	2.4771612	.4241316	2.3577590	.4448802	2.2477962	1
60	0.4040262	2.4750869	0.4244748	2.3558524	0.4452287	2.2460368	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	68°		67°		66°		

	24°		25°		26°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.4452287	2.2460368	0.4663077	2.1445069	0.4877326	2.0503038	60
1	.4455773	2.2442796	.4666618	2.1428793	.4880927	2.0487910	59
2	.4459260	2.2425247	.4670161	2.1412537	.4884530	2.0472800	58
3	.4462747	2.2407721	.4673705	2.1396301	.4888133	2.0457708	57
4	.4466236	2.2390218	.4677250	2.1380085	.4891737	2.0442634	56
5	.4469726	2.2372738	.4680796	2.1363890	.4895343	2.0427578	55
6	.4473216	2.2355280	.4684342	2.1347714	.4898949	2.0412540	54
7	.4476708	2.2337845	.4687890	2.1331559	.4902557	2.0397519	53
8	.4480200	2.2320433	.4691439	2.1315423	.4906166	2.0382517	52
9	.4483693	2.2303043	.4694988	2.1299308	.4909775	2.0367532	51
10	0.4487187	2.2285676	0.4698539	2.1283213	0.4913386	2.0352565	50
11	.4490682	2.2268331	.4702090	2.1267137	.4916997	2.0337615	49
12	.4494178	2.2251009	.4705643	2.1251082	.4920610	2.0322683	48
13	.4497675	2.2233709	.4709196	2.1235046	.4924224	2.0307769	47
14	.4501173	2.2216432	.4712751	2.1219030	.4927838	2.0292873	46
15	.4504672	2.2199177	.4716306	2.1203034	.4931454	2.0277994	45
16	.4508171	2.2181944	.4719863	2.1187057	.4935071	2.0263133	44
17	.4511672	2.2164733	.4723420	2.1171101	.4938689	2.0248289	43
18	.4515173	2.2147545	.4726978	2.1155164	.4942308	2.0233462	42
19	.4518676	2.2130379	.4730538	2.1139246	.4945928	2.0218654	41
20	0.4522179	2.2113234	0.4734098	2.1123348	0.4949549	2.0203862	40
21	.4525683	2.2096112	.4737659	2.1107470	.4953171	2.0189088	39
22	.4529188	2.2079012	.4741222	2.1091611	.4956794	2.0174331	38
23	.4532694	2.2061934	.4744785	2.1075771	.4960418	2.0159592	37
24	.4536201	2.2044878	.4748349	2.1059951	.4964043	2.0144869	36
25	.4539709	2.2027843	.4751914	2.1044150	.4967669	2.0130164	35
26	.4543218	2.2010831	.4755481	2.1028369	.4971297	2.0115477	34
27	.4546728	2.1993840	.4759048	2.1012607	.4974925	2.0100806	33
28	.4550238	2.1976871	.4762616	2.0996864	.4978554	2.0086153	32
29	.4553750	2.1959923	.4766185	2.0981140	.4982185	2.0071516	31
30	0.4557263	2.1942997	0.4769755	2.0965436	0.4985816	2.0056897	30
31	.4560776	2.1926093	.4773326	2.0949751	.4989449	2.0042295	29
32	.4564290	2.1909210	.4776899	2.0934085	.4993082	2.0027710	28
33	.4567806	2.1892349	.4780472	2.0918437	.4996717	2.0013142	27
34	.4571322	2.1875510	.4784046	2.0902809	.5000352	1.9998590	26
35	.4574839	2.1858691	.4787621	2.0887200	.5003989	1.9984056	25
36	.4578357	2.1841894	.4791197	2.0871610	.5007627	1.9969539	24
37	.4581877	2.1825119	.4794774	2.0856039	.5011266	1.9955038	23
38	.4585397	2.1808364	.4798352	2.0840487	.5014906	1.9940554	22
39	.4588918	2.1791631	.4801932	2.0824953	.5018547	1.9926087	21
40	0.4592439	2.1774920	0.4805512	2.0809438	0.5022189	1.9911637	20
41	.4595962	2.1758229	.4809093	2.0793942	.5025832	1.9897204	19
42	.4599486	2.1741559	.4812675	2.0778465	.5029476	1.9882787	18
43	.4603011	2.1724911	.4816258	2.0763007	.5033121	1.9868387	17
44	.4606537	2.1708283	.4819842	2.0747567	.5036768	1.9854003	16
45	.4610063	2.1691677	.4823427	2.0732146	.5040415	1.9839636	15
46	.4613591	2.1675091	.4827014	2.0716743	.5044063	1.9825286	14
47	.4617119	2.1658527	.4830601	2.0701359	.5047713	1.9810952	13
48	.4620649	2.1641983	.4834189	2.0685994	.5051363	1.9796635	12
49	.4624179	2.1625460	.4837778	2.0670646	.5055015	1.9782334	11
50	0.4627710	2.1608958	0.4841368	2.0655318	0.5058668	1.9768050	10
51	.4631243	2.1592476	.4844959	2.0640008	.5062322	1.9753782	9
52	.4634776	2.1576015	.4848552	2.0624716	.5065977	1.9739531	8
53	.4638310	2.1559575	.4852145	2.0609442	.5069633	1.9725296	7
54	.4641845	2.1543156	.4855739	2.0594187	.5073290	1.9711077	6
55	.4645382	2.1526757	.4859334	2.0578950	.5076948	1.9696874	5
56	.4648919	2.1510378	.4862931	2.0563732	.5080607	1.9682688	4
57	.4652457	2.1494021	.4866528	2.0548531	.5084267	1.9668518	3
58	.4655996	2.1477683	.4870126	2.0533349	.5087929	1.9654364	2
59	.4659536	2.1461366	.4873726	2.0518185	.5091591	1.9640227	1
60	0.4663077	2.1445069	0.4877326	2.0503038	0.5095254	1.9626105	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	65°		64°		63°		

	27°		28°		29°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.5095254	1.9626105	0.5317094	1.8807265	0.5543091	1.8040478	60
1	.5098919	1.9612000	.5320826	1.8794074	.5546894	1.8028108	59
2	.5102585	1.9597910	.5324559	1.8780898	.5550698	1.8015751	58
3	.5106252	1.9583837	.5328293	1.8767736	.5554504	1.8003408	57
4	.5109919	1.9569780	.5332029	1.8754588	.5558311	1.7991077	56
5	.5113588	1.9555739	.5335765	1.8741455	.5562119	1.7978759	55
6	.5117259	1.9541713	.5339503	1.8728336	.5565929	1.7966454	54
7	.5120930	1.9527704	.5343242	1.8715231	.5569739	1.7954162	53
8	.5124602	1.9513711	.5346981	1.8702141	.5573551	1.7941883	52
9	.5128275	1.9499733	.5350723	1.8689065	.5577364	1.7929616	51
10	0.5131950	1.9485772	0.5354465	1.8676003	0.5581179	1.7917362	50
11	.5135625	1.9471826	.5358208	1.8662955	.5584994	1.7905121	49
12	.5139302	1.9457896	.5361953	1.8649921	.5588811	1.7892893	48
13	.5142980	1.9443981	.5365699	1.8636902	.5592629	1.7880678	47
14	.5146658	1.9430083	.5369446	1.8623896	.5596449	1.7868475	46
15	.5150338	1.9416200	.5373194	1.8610905	.5600269	1.7856285	45
16	.5154019	1.9402333	.5376943	1.8597928	.5604091	1.7844107	44
17	.5157702	1.9388481	.5380694	1.8584965	.5607914	1.7831943	43
18	.5161385	1.9374645	.5384445	1.8572015	.5611738	1.7819790	42
19	.5165069	1.9360825	.5388198	1.8559080	.5615564	1.7807651	41
20	0.5168755	1.9347020	0.5391952	1.8546159	0.5619391	1.7795524	40
21	.5172441	1.9333231	.5395707	1.8533252	.5623219	1.7783409	39
22	.5176129	1.9319457	.5399464	1.8520358	.5627048	1.7771307	38
23	.5179818	1.9305699	.5403221	1.8507479	.5630879	1.7759218	37
24	.5183508	1.9291956	.5406980	1.8494613	.5634711	1.7747141	36
25	.5187199	1.9278228	.5410740	1.8481761	.5638543	1.7735076	35
26	.5190891	1.9264516	.5414501	1.8468923	.5642378	1.7723024	34
27	.5194584	1.9250819	.5418263	1.8456099	.5646213	1.7710985	33
28	.5198278	1.9237138	.5422027	1.8443289	.5650050	1.7698958	32
29	.5201974	1.9223472	.5425791	1.8430492	.5653888	1.7686943	31
30	0.5205671	1.9209821	0.5429557	1.8417709	0.5657728	1.7674940	30
31	.5209368	1.9196185	.5433324	1.8404940	.5661568	1.7662950	29
32	.5213067	1.9182565	.5437092	1.8392184	.5665410	1.7650972	28
33	.5216767	1.9168960	.5440862	1.8379442	.5669254	1.7639007	27
34	.5220468	1.9155370	.5444632	1.8366713	.5673098	1.7627053	26
35	.5224170	1.9141795	.5448404	1.8353999	.5676944	1.7615112	25
36	.5227874	1.9128236	.5452177	1.8341297	.5680791	1.7603183	24
37	.5231578	1.9114691	.5455951	1.8328610	.5684639	1.7591267	23
38	.5235284	1.9101162	.5459727	1.8315936	.5688488	1.7579362	22
39	.5238990	1.9087647	.5463503	1.8303275	.5692339	1.7567470	21
40	0.5242698	1.9074147	0.5467281	1.8290628	0.5696191	1.7555590	20
41	.5246407	1.9060663	.5471060	1.8277994	.5700045	1.7543722	19
42	.5250117	1.9047193	.5474840	1.8265374	.5703899	1.7531866	18
43	.5253829	1.9033738	.5478621	1.8252767	.5707755	1.7520023	17
44	.5257541	1.9020299	.5482404	1.8240173	.5711612	1.7508191	16
45	.5261255	1.9006874	.5486188	1.8227593	.5715471	1.7496371	15
46	.5264969	1.8993464	.5489973	1.8215026	.5719331	1.7484564	14
47	.5268685	1.8980068	.5493759	1.8202473	.5723192	1.7472768	13
48	.5272402	1.8966688	.5497547	1.8189933	.5727054	1.7460984	12
49	.5276120	1.8953322	.5501335	1.8177405	.5730918	1.7449213	11
50	0.5279839	1.8939971	0.5505125	1.8164892	0.5734783	1.7437453	10
51	.5283560	1.8926635	.5508916	1.8152391	.5738649	1.7425705	9
52	.5287281	1.8913313	.5512708	1.8139904	.5742516	1.7413969	8
53	.5291004	1.8900006	.5516502	1.8127430	.5746385	1.7402245	7
54	.5294727	1.8886713	.5520297	1.8114969	.5750255	1.7390533	6
55	.5298452	1.8873436	.5524093	1.8102521	.5754126	1.7378833	5
56	.5302178	1.8860172	.5527890	1.8090086	.5757999	1.7367144	4
57	.5305906	1.8846924	.5531688	1.8077664	.5761873	1.7355468	3
58	.5309634	1.8833690	.5535488	1.8065256	.5765748	1.7343803	2
59	.5313364	1.8820470	.5539288	1.8052860	.5769625	1.7332149	1
60	0.5317094	1.8807265	0.5543091	1.8040478	0.5773503	1.7320508	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	62°		61°		60°		

	30°		31°		32°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.5773503	1.7320508	0.6008606	1.6642795	0.6248694	1.6003345	60
1	.5777382	1.7308878	.6012566	1.6631834	.6252739	1.5992991	59
2	.5781262	1.7297260	.6016527	1.6620884	.6256786	1.5982647	58
3	.5785144	1.7285654	.6020490	1.6609945	.6260834	1.5972312	57
4	.5789027	1.7274060	.6024454	1.6599016	.6264884	1.5961987	56
5	.5792912	1.7262477	.6028419	1.6588097	.6268935	1.5951672	55
6	.5796797	1.7250905	.6032386	1.6577189	.6272988	1.5941366	54
7	.5800684	1.7239346	.6036354	1.6566292	.6277042	1.5931070	53
8	.5804573	1.7227797	.6040323	1.6555405	.6281098	1.5920783	52
9	.5808462	1.7216261	.6044294	1.6544529	.6285155	1.5910505	51
10	0.5812353	1.7204736	0.6048266	1.6533663	0.6289215	1.5900238	50
11	.5816245	1.7193222	.6052240	1.6522808	.6293274	1.5889979	49
12	.5820139	1.7181720	.6056215	1.6511963	.6297336	1.5879731	48
13	.5824034	1.7170230	.6060192	1.6501128	.6301399	1.5869491	47
14	.5827930	1.7158751	.6064170	1.6490304	.6305464	1.5859261	46
15	.5831828	1.7147283	.6068149	1.6479490	.6309530	1.5849041	45
16	.5835726	1.7135827	.6072130	1.6468687	.6313598	1.5838830	44
17	.5839627	1.7124382	.6076112	1.6457893	.6317667	1.5828628	43
18	.5843528	1.7112949	.6080095	1.6447111	.6321738	1.5818436	42
19	.5847431	1.7101527	.6084080	1.6436338	.6325810	1.5808253	41
20	0.5851335	1.7090116	0.6088067	1.6425576	0.6329883	1.5798079	40
21	.5855241	1.7078717	.6092054	1.6414824	.6333959	1.5787915	39
22	.5859148	1.7067329	.6096043	1.6404082	.6338035	1.5777760	38
23	.5863056	1.7055953	.6100034	1.6393351	.6342113	1.5767615	37
24	.5866965	1.7044587	.6104026	1.6382630	.6346193	1.5757479	36
25	.5870876	1.7033233	.6108019	1.6371919	.6350274	1.5747352	35
26	.5874788	1.7021890	.6112014	1.6361218	.6354357	1.5737234	34
27	.5878702	1.7010599	.6116011	1.6350528	.6358441	1.5727126	33
28	.5882616	1.6999238	.6120008	1.6339847	.6362527	1.5717026	32
29	.5886533	1.6987929	.6124007	1.6329177	.6366614	1.5706936	31
30	0.5890450	1.6976631	0.6128008	1.6318517	0.6370703	1.5696856	30
31	.5894369	1.6965344	.6132010	1.6307867	.6374793	1.5686784	29
32	.5898289	1.6954069	.6136014	1.6297227	.6378885	1.5676722	28
33	.5902211	1.6942804	.6140018	1.6286597	.6382978	1.5666669	27
34	.5906134	1.6931550	.6144024	1.6275977	.6387073	1.5656625	26
35	.5910058	1.6920308	.6148032	1.6265368	.6391169	1.5646590	25
36	.5913984	1.6909077	.6152041	1.6254768	.6395267	1.5636564	24
37	.5917910	1.6897856	.6156052	1.6244178	.6399366	1.5626548	23
38	.5921839	1.6886647	.6160064	1.6233599	.6403467	1.5616540	22
39	.5925768	1.6875449	.6164077	1.6223029	.6407569	1.5606542	21
40	0.5929699	1.6864261	0.6168092	1.6212469	0.6411673	1.5596552	20
41	.5933632	1.6853085	.6172108	1.6201920	.6415779	1.5586572	19
42	.5937565	1.6841919	.6176126	1.6191380	.6419886	1.5576601	18
43	.5941501	1.6830765	.6180145	1.6180850	.6423994	1.5566639	17
44	.5945437	1.6819621	.6184166	1.6170330	.6428105	1.5556685	16
45	.5949375	1.6808489	.6188188	1.6159820	.6432216	1.5546741	15
46	.5953314	1.6797367	.6192211	1.6149320	.6436329	1.5536806	14
47	.5957255	1.6786256	.6196236	1.6138829	.6440444	1.5526880	13
48	.5961196	1.6775156	.6200263	1.6128349	.6444560	1.5516963	12
49	.5965140	1.6764067	.6204291	1.6117878	.6448678	1.5507054	11
50	0.5969084	1.6752988	0.6208320	1.6107417	0.6452797	1.5497155	10
51	.5973030	1.6741921	.6212351	1.6096966	.6456918	1.5487264	9
52	.5976978	1.6730864	.6216383	1.6086525	.6461041	1.5477383	8
53	.5980926	1.6719818	.6220417	1.6076094	.6465165	1.5467510	7
54	.5984877	1.6708782	.6224452	1.6065672	.6469290	1.5457647	6
55	.5988828	1.6697758	.6228488	1.6055260	.6473417	1.5447792	5
56	.5992781	1.6686744	.6232527	1.6044858	.6477546	1.5437946	4
57	.5996735	1.6675741	.6236566	1.6034465	.6481676	1.5428108	3
58	.6000691	1.6664748	.6240607	1.6024082	.6485808	1.5418280	2
59	.6004648	1.6653766	.6244650	1.6013709	.6489941	1.5408460	1
60	0.6008606	1.6642795	0.6248694	1.6003345	0.6494076	1.5398650	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	59°		58°		57°		

	33°		34°		35°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.6494076	1.5398650	0.6745085	1.4825610	0.7002075	1.4281480	60
1	.6498212	1.5388848	.6749318	1.4816311	.7006411	1.4272642	59
2	.6502350	1.5379054	.6753553	1.4807021	.7010749	1.4263811	58
3	.6506490	1.5369270	.6757790	1.4797738	.7015089	1.4254988	57
4	.6510631	1.5359494	.6762028	1.4788463	.7019430	1.4246171	56
5	.6514774	1.5349727	.6766268	1.4779197	.7023773	1.4237362	55
6	.6518918	1.5339969	.6770509	1.4769938	.7028118	1.4228561	54
7	.6523064	1.5330219	.6774752	1.4760688	.7032464	1.4219766	53
8	.6527211	1.5320479	.6778997	1.4751445	.7036813	1.4210979	52
9	.6531360	1.5310746	.6783243	1.4742210	.7041163	1.4202200	51
10	0.6535511	1.5301023	0.6787492	1.4732983	0.7045515	1.4193427	50
11	.6539663	1.5291308	.6791741	1.4723764	.7049869	1.4184662	49
12	.6543817	1.5281602	.6795993	1.4714553	.7054224	1.4175904	48
13	.6547972	1.5271904	.6800246	1.4705350	.7058581	1.4167153	47
14	.6552129	1.5262215	.6804501	1.4696155	.7062940	1.4158409	46
15	.6556287	1.5252535	.6808758	1.4686967	.7067301	1.4149673	45
16	.6560447	1.5242863	.6813016	1.4677788	.7071664	1.4140943	44
17	.6564609	1.5233200	.6817276	1.4668616	.7076028	1.4132221	43
18	.6568772	1.5223545	.6821537	1.4659452	.7080395	1.4123506	42
19	.6572937	1.5213899	.6825801	1.4650296	.7084763	1.4114799	41
20	0.6577103	1.5204261	0.6830066	1.4641147	0.7089133	1.4106098	40
21	.6581271	1.5194632	.6834333	1.4632007	.7093504	1.4097405	39
22	.6585441	1.5185012	.6838601	1.4622874	.7097878	1.4088718	38
23	.6589612	1.5175400	.6842871	1.4613749	.7102253	1.4080039	37
24	.6593785	1.5165796	.6847143	1.4604632	.7106630	1.4071367	36
25	.6597960	1.5156201	.6851416	1.4595522	.7111009	1.4062702	35
26	.6602136	1.5146614	.6855692	1.4586420	.7115390	1.4054044	34
27	.6606313	1.5137036	.6859969	1.4577326	.7119772	1.4045393	33
28	.6610492	1.5127466	.6864247	1.4568240	.7124157	1.4036749	32
29	.6614673	1.5117905	.6868528	1.4559161	.7128543	1.4028113	31
30	0.6618856	1.5108352	0.6872810	1.4550090	0.7132931	1.4019483	30
31	.6623040	1.5098807	.6877093	1.4541027	.7137320	1.4010860	29
32	.6627225	1.5089271	.6881379	1.4531971	.7141712	1.4002245	28
33	.6631413	1.5079743	.6885666	1.4522923	.7146106	1.3993636	27
34	.6635601	1.5070224	.6889955	1.4513883	.7150501	1.3985034	26
35	.6639792	1.5060713	.6894246	1.4504850	.7154898	1.3976440	25
36	.6643984	1.5051210	.6898538	1.4495825	.7159297	1.3967852	24
37	.6648178	1.5041716	.6902832	1.4486808	.7163698	1.3959272	23
38	.6652373	1.5032229	.6907128	1.4477798	.7168100	1.3950698	22
39	.6656570	1.5022751	.6911425	1.4468796	.7172505	1.3942131	21
40	0.6660769	1.5013282	0.6915725	1.4459801	0.7176911	1.3933571	20
41	.6664969	1.5003821	.6920026	1.4450814	.7181319	1.3925019	19
42	.6669171	1.4994367	.6924328	1.4441834	.7185729	1.3916473	18
43	.6673374	1.4984923	.6928633	1.4432862	.7190140	1.3907934	17
44	.6677580	1.4975486	.6932939	1.4423897	.7194554	1.3899401	16
45	.6681786	1.4966058	.6937247	1.4414940	.7198970	1.3890876	15
46	.6685995	1.4956637	.6941557	1.4405991	.7203387	1.3882358	14
47	.6690205	1.4947225	.6945868	1.4397049	.7207806	1.3873847	13
48	.6694417	1.4937822	.6950181	1.4388114	.7212227	1.3865342	12
49	.6698630	1.4928426	.6954496	1.4379187	.7216650	1.3856844	11
50	0.6702845	1.4919039	0.6958813	1.4370268	0.7221075	1.3848353	10
51	.6707061	1.4909659	.6963131	1.4361356	.7225502	1.3839869	9
52	.6711280	1.4900288	.6967451	1.4352451	.7229930	1.3831392	8
53	.6715500	1.4890925	.6971773	1.4343554	.7234361	1.3822922	7
54	.6719721	1.4881570	.6976097	1.4334664	.7238793	1.3814458	6
55	.6723944	1.4872223	.6980422	1.4325781	.7243227	1.3806001	5
56	.6728169	1.4862884	.6984749	1.4316906	.7247663	1.3797551	4
57	.6732396	1.4853554	.6989078	1.4308039	.7252101	1.3789108	3
58	.6736624	1.4844231	.6993409	1.4299178	.7256540	1.3780672	2
59	.6740854	1.4834916	.6997741	1.4290326	.7260982	1.3772242	1
60	0.6745085	1.4825610	0.7002075	1.4281480	0.7265425	1.3763819	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	56°		55°		54°		

	36°		37°		38°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.7265425	1.3763819	0.7535541	1.3270448	0.7812856	1.2799416	60
1	.7269871	1.3755403	.7540102	1.3262420	.7817542	1.2791745	59
2	.7274318	1.3746994	.7544666	1.3254397	.7822229	1.2784079	58
3	.7278767	1.3738591	.7549232	1.3246381	.7826919	1.2776419	57
4	.7283218	1.3730195	.7553799	1.3238371	.7831611	1.2768765	56
5	.7287671	1.3721806	.7558369	1.3230368	.7836305	1.2761116	55
6	.7292125	1.3713423	.7562941	1.3222370	.7841002	1.2753473	54
7	.7296582	1.3705047	.7567514	1.3214379	.7845700	1.2745835	53
8	.7301041	1.3696678	.7572090	1.3206393	.7850400	1.2738204	52
9	.7305501	1.3688315	.7576668	1.3198414	.7855103	1.2730578	51
10	0.7309963	1.3679959	0.7581248	1.3190441	0.7859808	1.2722957	50
11	.7314428	1.3671610	.7585829	1.3182474	.7864515	1.2715342	49
12	.7318894	1.3663267	.7590413	1.3174513	.7869224	1.2707733	48
13	.7323362	1.3654931	.7594999	1.3166559	.7873935	1.2700130	47
14	.7327832	1.3646602	.7599587	1.3158610	.7878649	1.2692532	46
15	.7332303	1.3638279	.7604177	1.3150668	.7883364	1.2684940	45
16	.7336777	1.3629963	.7608769	1.3142731	.7888082	1.2677353	44
17	.7341253	1.3621653	.7613363	1.3134801	.7892802	1.2669772	43
18	.7345730	1.3613350	.7617959	1.3126876	.7897524	1.2662196	42
19	.7350210	1.3605054	.7622557	1.3118958	.7902248	1.2654626	41
20	0.7354691	1.3596764	0.7627157	1.3111046	0.7906975	1.2647062	40
21	.7359174	1.3588481	.7631759	1.3103140	.7911703	1.2639503	39
22	.7363660	1.3580204	.7636363	1.3095239	.7916434	1.2631950	38
23	.7368147	1.3571934	.7640969	1.3087345	.7921167	1.2624402	37
24	.7372636	1.3563670	.7645577	1.3079457	.7925902	1.2616860	36
25	.7377127	1.3555413	.7650188	1.3071575	.7930640	1.2609323	35
26	.7381620	1.3547162	.7654800	1.3063699	.7935379	1.2601792	34
27	.7386115	1.3538918	.7659414	1.3055828	.7940121	1.2594267	33
28	.7390611	1.3530680	.7664031	1.3047964	.7944865	1.2586747	32
29	.7395110	1.3522449	.7668649	1.3040106	.7949611	1.2579232	31
30	0.7399611	1.3514224	0.7673270	1.3032254	0.7954359	1.2571723	30
31	.7404113	1.3506006	.7677893	1.3024408	.7959110	1.2564219	29
32	.7408618	1.3497794	.7682517	1.3016567	.7963862	1.2556721	28
33	.7413124	1.3489589	.7687144	1.3008733	.7968617	1.2549229	27
34	.7417633	1.3481390	.7691773	1.3000904	.7973374	1.2541742	26
35	.7422143	1.3473198	.7696404	1.2993081	.7978134	1.2534260	25
36	.7426655	1.3465011	.7701037	1.2985265	.7982895	1.2526784	24
37	.7431170	1.3456832	.7705672	1.2977454	.7987659	1.2519313	23
38	.7435686	1.3448658	.7710309	1.2969649	.7992425	1.2511848	22
39	.7440204	1.3440492	.7714948	1.2961850	.7997193	1.2504388	21
40	0.7444724	1.3432331	0.7719589	1.2954057	0.8001963	1.2496933	20
41	.7449246	1.3424177	.7724233	1.2946270	.8006736	1.2489484	19
42	.7453770	1.3416029	.7728878	1.2938488	.8011511	1.2482040	18
43	.7458296	1.3407888	.7733526	1.2930713	.8016288	1.2474602	17
44	.7462824	1.3399753	.7738176	1.2922943	.8021067	1.2467169	16
45	.7467354	1.3391624	.7742827	1.2915179	.8025849	1.2459742	15
46	.7471886	1.3383502	.7747481	1.2907421	.8030632	1.2452320	14
47	.7476420	1.3375386	.7752137	1.2899669	.8035418	1.2444903	13
48	.7480956	1.3367276	.7756795	1.2891922	.8040206	1.2437492	12
49	.7485494	1.3359172	.7761455	1.2884182	.8044997	1.2430086	11
50	0.7490033	1.3351075	0.7766118	1.2876447	0.8049790	1.2422685	10
51	.7494575	1.3342984	.7770782	1.2868718	.8054584	1.2415290	9
52	.7499119	1.3334900	.7775448	1.2860995	.8059382	1.2407900	8
53	.7503665	1.3326822	.7780117	1.2853277	.8064181	1.2400515	7
54	.7508212	1.3318750	.7784788	1.2845566	.8068983	1.2393136	6
55	.7512762	1.3310684	.7789460	1.2837860	.8073787	1.2385762	5
56	.7517314	1.3302624	.7794135	1.2830160	.8078593	1.2378393	4
57	.7521867	1.3294571	.7798812	1.2822466	.8083401	1.2371030	3
58	.7526423	1.3286524	.7803492	1.2814776	.8088212	1.2363672	2
59	.7530981	1.3278483	.7808173	1.2807094	.8093025	1.2356319	1
60	0.7535541	1.3270448	0.7812856	1.2799416	0.8097840	1.2348972	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	53°		52°		51°		

	39°		40°		41°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.8097840	1.2348972	0.8390996	1.1917536	0.8692867	1.1503684	60
1	.8102658	1.2341629	.8395955	1.1910498	.8697976	1.1496928	59
2	.8107478	1.2334292	.8400915	1.1903465	.8703087	1.1490176	58
3	.8112300	1.2326961	.8405878	1.1896437	.8708200	1.1483429	57
4	.8117124	1.2319634	.8410844	1.1889414	.8713316	1.1476687	56
5	.8121951	1.2312313	.8415812	1.1882395	.8718435	1.1469949	55
6	.8126780	1.2304997	.8420782	1.1875382	.8723556	1.1463215	54
7	.8131611	1.2297687	.8425755	1.1868373	.8728680	1.1456486	53
8	.8136444	1.2290381	.8430730	1.1861369	.8733806	1.1449762	52
9	.8141280	1.2283081	.8435708	1.1854370	.8738935	1.1443041	51
10	0.8146118	1.2275786	0.8440688	1.1847376	0.8744067	1.1436326	50
11	.8150958	1.2268496	.8445670	1.1840387	.8749201	1.1429615	49
12	.8155801	1.2261211	.8450655	1.1833402	.8754338	1.1422908	48
13	.8160646	1.2253932	.8455643	1.1826422	.8759478	1.1416206	47
14	.8165493	1.2246658	.8460633	1.1819447	.8764620	1.1409508	46
15	.8170343	1.2239389	.8465625	1.1812477	.8769765	1.1402815	45
16	.8175195	1.2232125	.8470620	1.1805512	.8774912	1.1396126	44
17	.8180049	1.2224866	.8475617	1.1798551	.8780062	1.1389441	43
18	.8184905	1.2217613	.8480617	1.1791595	.8785215	1.1382761	42
19	.8189764	1.2210364	.8485619	1.1784644	.8790370	1.1376086	41
20	0.8194625	1.2203121	0.8490624	1.1777698	0.8795528	1.1369414	40
21	.8199488	1.2195883	.8495631	1.1770756	.8800688	1.1362747	39
22	.8204354	1.2188650	.8500640	1.1763820	.8805852	1.1356085	38
23	.8209222	1.2181422	.8505653	1.1756888	.8811017	1.1349427	37
24	.8214093	1.2174199	.8510667	1.1749960	.8816186	1.1342773	36
25	.8218965	1.2166982	.8515684	1.1743038	.8821357	1.1336124	35
26	.8223840	1.2159769	.8520704	1.1736120	.8826531	1.1329479	34
27	.8228718	1.2152562	.8525726	1.1729207	.8831707	1.1322839	33
28	.8233597	1.2145359	.8530750	1.1722298	.8836886	1.1316203	32
29	.8238479	1.2138162	.8535777	1.1715395	.8842068	1.1309571	31
30	0.8243364	1.2130970	0.8540807	1.1708496	0.8847253	1.1302944	30
31	.8248251	1.2123783	.8545839	1.1701601	.8852440	1.1296321	29
32	.8253140	1.2116601	.8550873	1.1694712	.8857630	1.1289702	28
33	.8258031	1.2109424	.8555910	1.1687827	.8862822	1.1283088	27
34	.8262925	1.2102252	.8560950	1.1680947	.8868017	1.1276478	26
35	.8267821	1.2095085	.8565992	1.1674071	.8873215	1.1269872	25
36	.8272719	1.2087924	.8571037	1.1667200	.8878415	1.1263271	24
37	.8277620	1.2080767	.8576084	1.1660334	.8883619	1.1256674	23
38	.8282523	1.2073615	.8581133	1.1653472	.8888825	1.1250081	22
39	.8287429	1.2066468	.8586185	1.1646615	.8894033	1.1243493	21
40	0.8292337	1.2059327	0.8591240	1.1639763	0.8899244	1.1236909	20
41	.8297247	1.2052190	.8596297	1.1632916	.8904458	1.1230329	19
42	.8302160	1.2045058	.8601357	1.1626073	.8909675	1.1223754	18
43	.8307075	1.2037932	.8606419	1.1619234	.8914894	1.1217183	17
44	.8311992	1.2030810	.8611484	1.1612400	.8920116	1.1210616	16
45	.8316912	1.2023693	.8616551	1.1605571	.8925341	1.1204053	15
46	.8321834	1.2016581	.8621621	1.1598747	.8930569	1.1197495	14
47	.8326759	1.2009475	.8626694	1.1591927	.8935799	1.1190941	13
48	.8331686	1.2002373	.8631768	1.1585112	.8941032	1.1184391	12
49	.8336615	1.1995276	.8636846	1.1578301	.8946268	1.1177846	11
50	0.8341547	1.1988184	0.8641926	1.1571495	0.8951506	1.1171305	10
51	.8346481	1.1981097	.8647009	1.1564693	.8956747	1.1164768	9
52	.8351418	1.1974015	.8652094	1.1557896	.8961991	1.1158235	8
53	.8356357	1.1966938	.8657181	1.1551104	.8967238	1.1151706	7
54	.8361298	1.1959866	.8662272	1.1544316	.8972487	1.1145182	6
55	.8366242	1.1952799	.8667365	1.1537532	.8977739	1.1138662	5
56	.8371188	1.1945736	.8672460	1.1530754	.8982994	1.1132146	4
57	.8376136	1.1938679	.8677558	1.1523979	.8988251	1.1125635	3
58	.8381087	1.1931626	.8682659	1.1517210	.8993512	1.1119127	2
59	.8386041	1.1924579	.8687762	1.1510445	.8998775	1.1112624	1
60	0.8390996	1.1917536	0.8692867	1.1503684	0.9004040	1.1106125	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	50°		49°		48°		

	42°		43°		44°		
	Tangent	Cotangent	Tangent	Cotangent	Tangent	Cotangent	
0	0.9004040	1.1106125	0.9325151	1.0723687	0.9656888	1.0355303	60
1	.9009309	1.1099630	.9330591	1.0717435	.9662511	1.0349277	59
2	.9014580	1.1093140	.9336034	1.0711187	.9668137	1.0343254	58
3	.9019854	1.1086653	.9341479	1.0704943	.9673767	1.0337235	57
4	.9025131	1.1080171	.9346928	1.0698702	.9679399	1.0331220	56
5	.9030411	1.1073693	.9352380	1.0692466	.9685035	1.0325208	55
6	.9035693	1.1067219	.9357834	1.0686233	.9690674	1.0319199	54
7	.9040979	1.1060750	.9363292	1.0680004	.9696316	1.0313195	53
8	.9046267	1.1054284	.9368753	1.0673779	.9701962	1.0307194	52
9	.9051557	1.1047823	.9374216	1.0667558	.9707610	1.0301196	51
10	0.9056851	1.1041365	0.9379683	1.0661341	0.9713262	1.0295203	50
11	.9062147	1.1034913	.9385153	1.0655128	.9718917	1.0289212	49
12	.9067446	1.1028463	.9390625	1.0648918	.9724575	1.0283226	48
13	.9072748	1.1022019	.9396101	1.0642713	.9730236	1.0277243	47
14	.9078053	1.1015578	.9401579	1.0636511	.9735901	1.0271263	46
15	.9083360	1.1009141	.9407061	1.0630313	.9741569	1.0265287	45
16	.9088671	1.1002709	.9412545	1.0624119	.9747240	1.0259315	44
17	.9093984	1.0996281	.9418033	1.0617929	.9752914	1.0253346	43
18	.9099300	1.0989857	.9423523	1.0611742	.9758591	1.0247381	42
19	.9104619	1.0983436	.9429017	1.0605560	.9764272	1.0241419	41
20	0.9109940	1.0977020	0.9434513	1.0599381	0.9769956	1.0235461	40
21	.9115265	1.0970609	.9440013	1.0593206	.9775643	1.0229506	39
22	.9120592	1.0964201	.9445516	1.0587035	.9781333	1.0223555	38
23	.9125922	1.0957797	.9451021	1.0580867	.9787027	1.0217608	37
24	.9131255	1.0951397	.9456530	1.0574704	.9792724	1.0211664	36
25	.9136591	1.0945002	.9462042	1.0568544	.9798424	1.0205723	35
26	.9141929	1.0938610	.9467556	1.0562388	.9804127	1.0199786	34
27	.9147270	1.0932223	.9473074	1.0556235	.9809833	1.0193853	33
28	.9152615	1.0925840	.9478595	1.0550087	.9815543	1.0187923	32
29	.9157962	1.0919460	.9484119	1.0543942	.9821256	1.0181997	31
30	0.9163312	1.0913085	0.9489646	1.0537801	0.9826973	1.0176074	30
31	.9168665	1.0906714	.9495176	1.0531664	.9832692	1.0170155	29
32	.9174020	1.0900347	.9500709	1.0525531	.9838415	1.0164239	28
33	.9179379	1.0893984	.9506245	1.0519401	.9844141	1.0158326	27
34	.9184740	1.0887624	.9511784	1.0513275	.9849871	1.0152418	26
35	.9190104	1.0881269	.9517326	1.0507153	.9855603	1.0146512	25
36	.9195471	1.0874918	.9522871	1.0501034	.9861339	1.0140610	24
37	.9200841	1.0868571	.9528420	1.0494920	.9867079	1.0134712	23
38	.9206214	1.0862228	.9533971	1.0488809	.9872821	1.0128817	22
39	.9211590	1.0855889	.9539526	1.0482702	.9878567	1.0122925	21
40	0.9216969	1.0849554	0.9545083	1.0476598	0.9884316	1.0117038	20
41	.9222350	1.0843223	.9550644	1.0470498	.9890069	1.0111153	19
42	.9227734	1.0836896	.9556208	1.0464402	.9895825	1.0105272	18
43	.9233122	1.0830573	.9561774	1.0458310	.9901584	1.0099394	17
44	.9238512	1.0824254	.9567344	1.0452221	.9907346	1.0093520	16
45	.9243905	1.0817939	.9572917	1.0446136	.9913112	1.0087649	15
46	.9249301	1.0811628	.9578494	1.0440055	.9918881	1.0081782	14
47	.9254700	1.0805321	.9584073	1.0433977	.9924654	1.0075918	13
48	.9260102	1.0799018	.9589655	1.0427904	.9930429	1.0070058	12
49	.9265506	1.0792718	.9595241	1.0421833	.9936208	1.0064201	11
50	0.9270914	1.0786423	0.9600829	1.0415767	0.9941991	1.0058348	10
51	.9276324	1.0780132	.9606421	1.0409704	.9947777	1.0052497	9
52	.9281738	1.0773845	.9612016	1.0403645	.9953566	1.0046651	8
53	.9287154	1.0767561	.9617614	1.0397589	.9959358	1.0040808	7
54	.9292573	1.0761282	.9623215	1.0391538	.9965154	1.0034968	6
55	.9297996	1.0755006	.9628819	1.0385489	.9970953	1.0029131	5
56	.9303421	1.0748734	.9634427	1.0379445	.9976756	1.0023298	4
57	.9308849	1.0742467	.9640037	1.0373404	.9982562	1.0017469	3
58	.9314280	1.0736203	.9645651	1.0367367	.9988371	1.0011642	2
59	.9319714	1.0729943	.9651268	1.0361333	.9994184	1.0005819	1
60	0.9325151	1.0723687	0.9656888	1.0355303	1.0000000	1.0000000	0
	Cotangent	Tangent	Cotangent	Tangent	Cotangent	Tangent	
	47°		46°		45°		

	0°		1°		2°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0000000	0.0000000	0.0001523	0.0001523	0.0006092	0.0006095	0
1	.0000000	.0000000	.0001574	.0001574	.0006194	.0006198	1
2	.0000002	.0000002	.0001626	.0001627	.0006296	.0006300	2
3	.0000004	.0000004	.0001679	.0001679	.0006400	.0006404	3
4	.0000007	.0000007	.0001733	.0001733	.0006505	.0006509	4
5	.0000011	.0000011	.0001787	.0001788	.0006610	.0006614	5
6	.0000015	.0000015	.0001843	.0001843	.0006716	.0006721	6
7	.0000021	.0000021	.0001899	.0001900	.0006823	.0006828	7
8	.0000027	.0000027	.0001956	.0001957	.0006931	.0006936	8
9	.0000034	.0000034	.0002014	.0002015	.0007040	.0007045	9
10	0.0000042	0.0000042	0.0002073	0.0002073	0.0007149	0.0007154	10
11	.0000051	.0000051	.0002133	.0002133	.0007260	.0007265	11
12	.0000061	.0000061	.0002193	.0002194	.0007371	.0007376	12
13	.0000072	.0000072	.0002255	.0002255	.0007483	.0007489	13
14	.0000083	.0000083	.0002317	.0002317	.0007596	.0007602	14
15	.0000095	.0000095	.0002380	.0002380	.0007710	.0007716	15
16	.0000108	.0000108	.0002444	.0002444	.0007824	.0007830	16
17	.0000122	.0000122	.0002508	.0002509	.0007940	.0007946	17
18	.0000137	.0000137	.0002574	.0002575	.0008056	.0008063	18
19	.0000153	.0000153	.0002640	.0002641	.0008173	.0008180	19
20	0.0000169	0.0000169	0.0002708	0.0002708	0.0008291	0.0008298	20
21	.0000187	.0000187	.0002776	.0002776	.0008410	.0008417	21
22	.0000205	.0000205	.0002844	.0002845	.0008530	.0008537	22
23	.0000224	.0000224	.0002914	.0002915	.0008650	.0008658	23
24	.0000244	.0000244	.0002985	.0002986	.0008772	.0008779	24
25	.0000264	.0000264	.0003057	.0003058	.0008894	.0008902	25
26	.0000286	.0000286	.0003129	.0003130	.0009017	.0009025	26
27	.0000308	.0000308	.0003202	.0003203	.0009141	.0009149	27
28	.0000332	.0000332	.0003276	.0003277	.0009266	.0009274	28
29	.0000356	.0000356	.0003351	.0003352	.0009391	.0009400	29
30	0.0000381	0.0000381	0.0003427	0.0003428	0.0009518	0.0009527	30
31	.0000407	.0000407	.0003503	.0003505	.0009645	.0009654	31
32	.0000433	.0000433	.0003581	.0003582	.0009773	.0009783	32
33	.0000461	.0000461	.0003659	.0003660	.0009902	.0009912	33
34	.0000489	.0000489	.0003738	.0003739	.0010032	.0010042	34
35	.0000518	.0000518	.0003818	.0003820	.0010163	.0010173	35
36	.0000548	.0000548	.0003899	.0003900	.0010294	.0010305	36
37	.0000579	.0000579	.0003980	.0003982	.0010427	.0010438	37
38	.0000611	.0000611	.0004063	.0004065	.0010560	.0010571	38
39	.0000643	.0000644	.0004146	.0004148	.0010694	.0010705	39
40	0.0000677	0.0000677	0.0004230	0.0004232	0.0010829	0.0010841	40
41	.0000711	.0000711	.0004316	.0004317	.0010965	.0010977	41
42	.0000746	.0000746	.0004401	.0004403	.0011101	.0011114	42
43	.0000782	.0000782	.0004488	.0004490	.0011239	.0011251	43
44	.0000819	.0000819	.0004576	.0004578	.0011377	.0011390	44
45	.0000857	.0000857	.0004664	.0004666	.0011516	.0011529	45
46	.0000895	.0000895	.0004753	.0004756	.0011656	.0011670	46
47	.0000935	.0000935	.0004843	.0004846	.0011797	.0011811	47
48	.0000975	.0000975	.0004934	.0004937	.0011939	.0011953	48
49	.0001016	.0001016	.0005026	.0005029	.0012081	.0012096	49
50	0.0001058	0.0001058	0.0005119	0.0005121	0.0012225	0.0012239	50
51	.0001100	.0001101	.0005212	.0005215	.0012369	.0012384	51
52	.0001144	.0001144	.0005307	.0005309	.0012514	.0012529	52
53	.0001188	.0001189	.0005402	.0005405	.0012660	.0012676	53
54	.0001234	.0001234	.0005498	.0005501	.0012806	.0012823	54
55	.0001280	.0001280	.0005595	.0005598	.0012954	.0012971	55
56	.0001327	.0001327	.0005692	.0005696	.0013102	.0013120	56
57	.0001375	.0001375	.0005791	.0005794	.0013252	.0013269	57
58	.0001423	.0001423	.0005890	.0005894	.0013402	.0013420	58
59	.0001473	.0001473	.0005991	.0005994	.0013553	.0013571	59
60	0.0001523	0.0001523	0.0006092	0.0006095	0.0013705	0.0013723	60

	3°		4°		5°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0013705	0.0013723	0.0024359	0.0024419	0.0038053	0.0038198	0
1	.0013857	.0013877	.0024563	.0024623	.0038307	.0038454	1
2	.0014011	.0014030	.0024767	.0024829	.0038562	.0038711	2
3	.0014165	.0014185	.0024972	.0025035	.0038817	.0038969	3
4	.0014320	.0014341	.0025178	.0025241	.0039074	.0039227	4
5	.0014476	.0014497	.0025385	.0025449	.0039331	.0039486	5
6	.0014633	.0014655	.0025592	.0025658	.0039589	.0039747	6
7	.0014791	.0014813	.0025801	.0025867	.0039848	.0040008	7
8	.0014950	.0014972	.0026010	.0026078	.0040108	.0040270	8
9	.0015109	.0015132	.0026220	.0026289	.0040369	.0040533	9
10	0.0015269	0.0015293	0.0026431	0.0026501	0.0040630	0.0040796	10
11	.0015430	.0015454	.0026643	.0026714	.0040893	.0041061	11
12	.0015592	.0015617	.0026855	.0026928	.0041156	.0041326	12
13	.0015755	.0015780	.0027069	.0027142	.0041420	.0041592	13
14	.0015919	.0015944	.0027283	.0027358	.0041685	.0041859	14
15	.0016083	.0016109	.0027498	.0027574	.0041951	.0042127	15
16	.0016249	.0016275	.0027714	.0027791	.0042217	.0042396	16
17	.0016415	.0016442	.0027931	.0028009	.0042485	.0042666	17
18	.0016582	.0016609	.0028149	.0028228	.0042753	.0042937	18
19	.0016750	.0016778	.0028367	.0028448	.0043022	.0043208	19
20	0.0016918	0.0016947	0.0028587	0.0028669	0.0043292	0.0043480	20
21	.0017088	.0017117	.0028807	.0028890	.0043563	.0043753	21
22	.0017258	.0017288	.0029028	.0029112	.0043835	.0044028	22
23	.0017430	.0017460	.0029250	.0029336	.0044107	.0044302	23
24	.0017602	.0017633	.0029472	.0029560	.0044380	.0044578	24
25	.0017775	.0017806	.0029696	.0029785	.0044655	.0044855	25
26	.0017948	.0017981	.0029920	.0030010	.0044930	.0045132	26
27	.0018123	.0018156	.0030146	.0030237	.0045205	.0045411	27
28	.0018299	.0018332	.0030372	.0030464	.0045482	.0045690	28
29	.0018475	.0018509	.0030599	.0030693	.0045760	.0045970	29
30	0.0018652	0.0018687	0.0030827	0.0030922	0.0046038	0.0046251	30
31	.0018830	.0018866	.0031055	.0031152	.0046317	.0046533	31
32	.0019009	.0019045	.0031285	.0031383	.0046597	.0046815	32
33	.0019189	.0019225	.0031515	.0031615	.0046878	.0047099	33
34	.0019369	.0019407	.0031746	.0031847	.0047160	.0047383	34
35	.0019550	.0019589	.0031978	.0032081	.0047443	.0047669	35
36	.0019733	.0019772	.0032211	.0032315	.0047726	.0047955	36
37	.0019916	.0019956	.0032445	.0032551	.0048010	.0048242	37
38	.0020100	.0020140	.0032679	.0032787	.0048295	.0048530	38
39	.0020284	.0020326	.0032915	.0033024	.0048581	.0048819	39
40	0.0020470	0.0020512	0.0033151	0.0033261	0.0048868	0.0049108	40
41	.0020657	.0020699	.0033388	.0033500	.0049156	.0049399	41
42	.0020844	.0020887	.0033626	.0033740	.0049444	.0049690	42
43	.0021032	.0021076	.0033865	.0033980	.0049734	.0049982	43
44	.0021221	.0021266	.0034105	.0034221	.0050024	.0050275	44
45	.0021411	.0021457	.0034345	.0034463	.0050315	.0050569	45
46	.0021601	.0021648	.0034586	.0034706	.0050607	.0050864	46
47	.0021793	.0021841	.0034828	.0034950	.0050899	.0051160	47
48	.0021985	.0022034	.0035071	.0035195	.0051193	.0051456	48
49	.0022179	.0022228	.0035315	.0035440	.0051487	.0051754	49
50	0.0022373	0.0022423	0.0035560	0.0035687	0.0051783	0.0052052	50
51	.0022567	.0022619	.0035805	.0035934	.0052079	.0052351	51
52	.0022763	.0022815	.0036052	.0036182	.0052375	.0052651	52
53	.0022960	.0023013	.0036299	.0036431	.0052673	.0052952	53
54	.0023157	.0023211	.0036547	.0036681	.0052972	.0053254	54
55	.0023355	.0023410	.0036796	.0036932	.0053271	.0053557	55
56	.0023555	.0023610	.0037046	.0037183	.0053572	.0053860	56
57	.0023755	.0023811	.0037296	.0037436	.0053873	.0054164	57
58	.0023955	.0024013	.0037548	.0037689	.0054175	.0054470	58
59	.0024157	.0024216	.0037800	.0037943	.0054477	.0054776	59
60	0.0024359	0.0024419	0.0038053	0.0038198	0.0054781	0.0055083	60

	6°		7°		8°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0054781	0.0055083	0.0074538	0.0075098	0.0097319	0.0098276	0
1	.0055086	.0055391	.0074893	.0075459	.0097725	.0098689	1
2	.0055391	.0055699	.0075249	.0075820	.0098131	.0099103	2
3	.0055697	.0056009	.0075606	.0076182	.0098538	.0099518	3
4	.0056004	.0056319	.0075963	.0076545	.0098945	.0099934	4
5	.0056312	.0056631	.0076321	.0076908	.0099354	.0100351	5
6	.0056621	.0056943	.0076681	.0077273	.0099763	.0100769	6
7	.0056930	.0057256	.0077041	.0077639	.0100174	.0101187	7
8	.0057240	.0057570	.0077401	.0078005	.0100585	.0101607	8
9	.0057552	.0057885	.0077763	.0078372	.0100997	.0102027	9
10	0.0057864	0.0058200	0.0078126	0.0078741	0.0101410	0.0102449	10
11	.0058177	.0058517	.0078489	.0079110	.0101823	.0102871	11
12	.0058490	.0058834	.0078853	.0079480	.0102238	.0103294	12
13	.0058805	.0059153	.0079218	.0079851	.0102653	.0103718	13
14	.0059120	.0059472	.0079584	.0080222	.0103069	.0104143	14
15	.0059437	.0059792	.0079951	.0080595	.0103486	.0104568	15
16	.0059754	.0060113	.0080318	.0080968	.0103904	.0104995	16
17	.0060072	.0060435	.0080686	.0081343	.0104323	.0105422	17
18	.0060390	.0060757	.0081056	.0081718	.0104742	.0105851	18
19	.0060710	.0061081	.0081426	.0082094	.0105162	.0106280	19
20	0.0061031	0.0061405	0.0081796	0.0082471	0.0105584	0.0106710	20
21	.0061352	.0061731	.0082168	.0082849	.0106006	.0107141	21
22	.0061674	.0062057	.0082541	.0083228	.0106428	.0107573	22
23	.0061997	.0062384	.0082914	.0083607	.0106852	.0108006	23
24	.0062321	.0062712	.0083288	.0083988	.0107277	.0108440	24
25	.0062645	.0063040	.0083663	.0084369	.0107702	.0108875	25
26	.0062971	.0063370	.0084039	.0084752	.0108128	.0109310	26
27	.0063297	.0063701	.0084416	.0085135	.0108555	.0109747	27
28	.0063625	.0064032	.0084794	.0085519	.0108983	.0110184	28
29	.0063953	.0064364	.0085172	.0085904	.0109412	.0110622	29
30	0.0064281	0.0064697	0.0085551	0.0086290	0.0109841	0.0111061	30
31	.0064611	.0065031	.0085931	.0086676	.0110272	.0111501	31
32	.0064942	.0065366	.0086312	.0087064	.0110703	.0111942	32
33	.0065273	.0065702	.0086694	.0087452	.0111135	.0112384	33
34	.0065605	.0066039	.0087077	.0087842	.0111568	.0112827	34
35	.0065938	.0066376	.0087460	.0088232	.0112002	.0113270	35
36	.0066272	.0066714	.0087845	.0088623	.0112436	.0113715	36
37	.0066607	.0067054	.0088230	.0089015	.0112872	.0114160	37
38	.0066943	.0067394	.0088616	.0089408	.0113308	.0114606	38
39	.0067279	.0067735	.0089003	.0089802	.0113745	.0115054	39
40	0.0067616	0.0068077	0.0089390	0.0090196	0.0114183	0.0115502	40
41	.0067955	.0068419	.0089779	.0090592	.0114622	.0115951	41
42	.0068294	.0068763	.0090168	.0090988	.0115061	.0116400	42
43	.0068633	.0069108	.0090558	.0091386	.0115502	.0116851	43
44	.0068974	.0069453	.0090949	.0091784	.0115943	.0117303	44
45	.0069315	.0069799	.0091341	.0092183	.0116385	.0117755	45
46	.0069658	.0070146	.0091734	.0092583	.0116828	.0118209	46
47	.0070001	.0070494	.0092127	.0092984	.0117272	.0118663	47
48	.0070345	.0070843	.0092522	.0093386	.0117716	.0119118	48
49	.0070690	.0071193	.0092917	.0093788	.0118162	.0119575	49
50	0.0071035	0.0071544	0.0093313	0.0094192	0.0118608	0.0120032	50
51	.0071382	.0071895	.0093710	.0094596	.0119055	.0120489	51
52	.0071729	.0072248	.0094107	.0095001	.0119503	.0120948	52
53	.0072078	.0072601	.0094506	.0095408	.0119952	.0121408	53
54	.0072427	.0072955	.0094905	.0095815	.0120401	.0121869	54
55	.0072776	.0073310	.0095306	.0096223	.0120852	.0122330	55
56	.0073127	.0073666	.0095707	.0096631	.0121303	.0122793	56
57	.0073479	.0074023	.0096109	.0097041	.0121755	.0123256	57
58	.0073831	.0074380	.0096511	.0097452	.0122208	.0123720	58
59	.0074184	.0074739	.0096915	.0097863	.0122662	.0124185	59
60	0.0074538	0.0075098	0.0097319	0.0098276	0.0123117	0.0124651	60

	9°		10°		11°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0123117	0.0124651	0.0151922	0.0154266	0.0183728	0.0187167	0
1	.0123572	.0125118	.0152428	.0154787	.0184284	.0187743	1
2	.0124028	.0125586	.0152934	.0155310	.0184840	.0188321	2
3	.0124486	.0126055	.0153442	.0155833	.0185397	.0188899	3
4	.0124943	.0126524	.0153950	.0156357	.0185955	.0189478	4
5	.0125402	.0126995	.0154458	.0156882	.0186514	.0190059	5
6	.0125862	.0127466	.0154968	.0157408	.0187073	.0190640	6
7	.0126322	.0127939	.0155479	.0157934	.0187634	.0191222	7
8	.0126784	.0128412	.0155990	.0158462	.0188195	.0191805	8
9	.0127246	.0128886	.0156502	.0158991	.0188757	.0192389	9
10	0.0127709	0.0129361	0.0157015	0.0159520	0.0189320	0.0192973	10
11	.0128173	.0129837	.0157529	.0160050	.0189884	.0193559	11
12	.0128637	.0130314	.0158044	.0160582	.0190448	.0194146	12
13	.0129103	.0130791	.0158559	.0161114	.0191014	.0194734	13
14	.0129569	.0131270	.0159076	.0161647	.0191580	.0195322	14
15	.0130036	.0131750	.0159593	.0162181	.0192147	.0195912	15
16	.0130504	.0132230	.0160111	.0162716	.0192715	.0196502	16
17	.0130973	.0132711	.0160630	.0163252	.0193284	.0197093	17
18	.0131443	.0133194	.0161150	.0163789	.0193853	.0197686	18
19	.0131913	.0133677	.0161670	.0164327	.0194424	.0198279	19
20	0.0132385	0.0134161	0.0162192	0.0164865	0.0194995	0.0198873	20
21	.0132857	.0134646	.0162714	.0165405	.0195567	.0199468	21
22	.0133330	.0135132	.0163237	.0165946	.0196140	.0200064	22
23	.0133804	.0135618	.0163761	.0166487	.0196714	.0200661	23
24	.0134278	.0136106	.0164285	.0167029	.0197288	.0201259	24
25	.0134754	.0136595	.0164811	.0167573	.0197864	.0201858	25
26	.0135230	.0137084	.0165337	.0168117	.0198440	.0202457	26
27	.0135707	.0137574	.0165864	.0168662	.0199017	.0203058	27
28	.0136185	.0138066	.0166392	.0169208	.0199595	.0203660	28
29	.0136664	.0138558	.0166921	.0169755	.0200173	.0204262	29
30	0.0137144	0.0139051	0.0167451	0.0170303	0.0200753	0.0204866	30
31	.0137625	.0139545	.0167981	.0170851	.0201333	.0205470	31
32	.0138106	.0140040	.0168513	.0171401	.0201914	.0206075	32
33	.0138588	.0140536	.0169045	.0171952	.0202496	.0206682	33
34	.0139071	.0141032	.0169578	.0172503	.0203079	.0207289	34
35	.0139555	.0141530	.0170112	.0173056	.0203663	.0207897	35
36	.0140040	.0142029	.0170647	.0173609	.0204248	.0208506	36
37	.0140525	.0142528	.0171182	.0174163	.0204833	.0209116	37
38	.0141012	.0143028	.0171718	.0174719	.0205419	.0209727	38
39	.0141499	.0143530	.0172256	.0175275	.0206006	.0210339	39
40	0.0141987	0.0144032	0.0172794	0.0175832	0.0206594	0.0210952	40
41	.0142476	.0144535	.0173332	.0176390	.0207182	.0211566	41
42	.0142965	.0145039	.0173872	.0176949	.0207772	.0212180	42
43	.0143456	.0145544	.0174413	.0177509	.0208362	.0212796	43
44	.0143947	.0146050	.0174954	.0178069	.0208953	.0213413	44
45	.0144439	.0146556	.0175496	.0178631	.0209545	.0214030	45
46	.0144932	.0147064	.0176039	.0179194	.0210138	.0214649	46
47	.0145426	.0147572	.0176583	.0179757	.0210732	.0215268	47
48	.0145921	.0148082	.0177127	.0180321	.0211326	.0215888	48
49	.0146417	.0148592	.0177673	.0180887	.0211921	.0216510	49
50	0.0146913	0.0149103	0.0178219	0.0181453	0.0212517	0.0217132	50
51	.0147410	.0149616	.0178766	.0182020	.0213114	.0217755	51
52	.0147908	.0150129	.0179314	.0182588	.0213712	.0218379	52
53	.0148407	.0150643	.0179863	.0183158	.0214311	.0219004	53
54	.0148907	.0151158	.0180413	.0183728	.0214910	.0219630	54
55	.0149407	.0151673	.0180963	.0184298	.0215510	.0220257	55
56	.0149909	.0152190	.0181515	.0184870	.0216111	.0220885	56
57	.0150411	.0152708	.0182067	.0185443	.0216713	.0221514	57
58	.0150914	.0153226	.0182620	.0186017	.0217316	.0222144	58
59	.0151418	.0153746	.0183174	.0186591	.0217920	.0222774	59
60	0.0151922	0.0154266	0.0183728	0.0187167	0.0218524	0.0223406	60

	12°		13°		14°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0218524	0.0223406	0.0256299	0.0263041	0.0297043	0.0306136	0
1	.0219129	.0224039	.0256954	.0263731	.0297747	.0306884	1
2	.0219735	.0224672	.0257610	.0264421	.0298452	.0307633	2
3	.0220342	.0225307	.0258266	.0265113	.0299158	.0308383	3
4	.0220950	.0225942	.0258923	.0265806	.0299864	.0309134	4
5	.0221558	.0226578	.0259581	.0266499	.0300572	.0309886	5
6	.0222168	.0227216	.0260240	.0267194	.0301280	.0310639	6
7	.0222778	.0227854	.0260900	.0267889	.0301989	.0311393	7
8	.0223389	.0228493	.0261561	.0268586	.0302699	.0312147	8
9	.0224001	.0229133	.0262222	.0269283	.0303409	.0312903	9
10	0.0224613	0.0229774	0.0262884	0.0269982	0.0304121	0.0313660	10
11	.0225227	.0230416	.0263547	.0270681	.0304833	.0314418	11
12	.0225841	.0231059	.0264211	.0271381	.0305547	.0315177	12
13	.0226456	.0231703	.0264876	.0272082	.0306260	.0315936	13
14	.0227072	.0232348	.0265541	.0272785	.0306975	.0316697	14
15	.0227689	.0232994	.0266207	.0273488	.0307691	.0317459	15
16	.0228307	.0233641	.0266875	.0274192	.0308407	.0318222	16
17	.0228925	.0234288	.0267542	.0274897	.0309125	.0318985	17
18	.0229544	.0234937	.0268211	.0275603	.0309843	.0319750	18
19	.0230164	.0235587	.0268881	.0276310	.0310562	.0320516	19
20	0.0230785	0.0236237	0.0269551	0.0277018	0.0311281	0.0321282	20
21	.0231407	.0236889	.0270223	.0277727	.0312002	.0322050	21
22	.0232030	.0237541	.0270895	.0278437	.0312723	.0322818	22
23	.0232653	.0238195	.0271568	.0279148	.0313445	.0323588	23
24	.0233277	.0238849	.0272241	.0279860	.0314168	.0324359	24
25	.0233902	.0239504	.0272916	.0280573	.0314892	.0325130	25
26	.0234528	.0240161	.0273591	.0281287	.0315617	.0325903	26
27	.0235155	.0240818	.0274267	.0282002	.0316342	.0326676	27
28	.0235782	.0241476	.0274944	.0282717	.0317069	.0327451	28
29	.0236411	.0242135	.0275622	.0283434	.0317796	.0328227	29
30	0.0237040	0.0242795	0.0276301	0.0284152	0.0318524	0.0329003	30
31	.0237670	.0243456	.0276980	.0284871	.0319252	.0329781	31
32	.0238301	.0244118	.0277661	.0285590	.0319982	.0330559	32
33	.0238932	.0244781	.0278342	.0286311	.0320712	.0331339	33
34	.0239565	.0245445	.0279024	.0287033	.0321443	.0332119	34
35	.0240198	.0246110	.0279706	.0287755	.0322175	.0332901	35
36	.0240832	.0246776	.0280390	.0288479	.0322908	.0333683	36
37	.0241467	.0247442	.0281074	.0289203	.0323642	.0334467	37
38	.0242103	.0248110	.0281760	.0289929	.0324376	.0335251	38
39	.0242740	.0248779	.0282446	.0290655	.0325112	.0336037	39
40	0.0243377	0.0249448	0.0283133	0.0291383	0.0325848	0.0336823	40
41	.0244015	.0250119	.0283820	.0292111	.0326585	.0337611	41
42	.0244655	.0250790	.0284509	.0292840	.0327322	.0338399	42
43	.0245294	.0251463	.0285198	.0293571	.0328061	.0339188	43
44	.0245935	.0252136	.0285888	.0294302	.0328800	.0339979	44
45	.0246577	.0252811	.0286579	.0295034	.0329541	.0340770	45
46	.0247219	.0253486	.0287271	.0295768	.0330282	.0341563	46
47	.0247862	.0254162	.0287964	.0296502	.0331023	.0342356	47
48	.0248506	.0254839	.0288657	.0297237	.0331766	.0343151	48
49	.0249151	.0255518	.0289351	.0297973	.0332510	.0343946	49
50	0.0249797	0.0256197	0.0290047	0.0298711	0.0333254	0.0344743	50
51	.0250444	.0256877	.0290742	.0299449	.0333999	.0345540	51
52	.0251091	.0257558	.0291439	.0300188	.0334745	.0346338	52
53	.0251739	.0258240	.0292137	.0300928	.0335492	.0347138	53
54	.0252388	.0258923	.0292835	.0301669	.0336239	.0347938	54
55	.0253038	.0259607	.0293534	.0302411	.0336988	.0348740	55
56	.0253689	.0260292	.0294234	.0303154	.0337737	.0349542	56
57	.0254340	.0260978	.0294935	.0303898	.0338487	.0350346	57
58	.0254992	.0261665	.0295637	.0304643	.0339238	.0351150	58
59	.0255645	.0262352	.0296339	.0305389	.0339989	.0351955	59
60	0.0256299	0.0263041	0.0297043	0.0306136	0.0340742	0.0352762	60

	15°		16°		17°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0340742	0.0352762	0.0387383	0.0402994	0.0436952	0.0456918	0
1	.0341495	.0353569	.0388185	.0403863	.0437803	.0457848	1
2	.0342249	.0354378	.0388988	.0404732	.0438655	.0458780	2
3	.0343004	.0355187	.0389792	.0405602	.0439508	.0459712	3
4	.0343760	.0355998	.0390597	.0406473	.0440361	.0460646	4
5	.0344516	.0356809	.0391402	.0407346	.0441215	.0461581	5
6	.0345274	.0357621	.0392208	.0408219	.0442070	.0462516	6
7	.0346032	.0358435	.0393016	.0409094	.0442926	.0463453	7
8	.0346791	.0359249	.0393823	.0409969	.0443782	.0464391	8
9	.0347551	.0360065	.0394632	.0410845	.0444639	.0465330	9
10	0.0348311	0.0360881	0.0395442	0.0411723	0.0445498	0.0466270	10
11	.0349073	.0361699	.0396252	.0412601	.0446357	.0467211	11
12	.0349835	.0362517	.0397063	.0413481	.0447216	.0468153	12
13	.0350598	.0363337	.0397875	.0414362	.0448077	.0469096	13
14	.0351362	.0364157	.0398688	.0415243	.0448938	.0470040	14
15	.0352127	.0364979	.0399501	.0416126	.0449801	.0470986	15
16	.0352892	.0365801	.0400316	.0417009	.0450664	.0471932	16
17	.0353659	.0366625	.0401131	.0417894	.0451527	.0472879	17
18	.0354426	.0367449	.0401947	.0418780	.0452392	.0473828	18
19	.0355194	.0368275	.0402764	.0419667	.0453257	.0474777	19
20	0.0355963	0.0369101	0.0403582	0.0420554	0.0454124	0.0475728	20
21	.0356732	.0369929	.0404400	.0421443	.0454991	.0476679	21
22	.0357503	.0370757	.0405219	.0422333	.0455859	.0477632	22
23	.0358274	.0371587	.0406039	.0423224	.0456727	.0478586	23
24	.0359046	.0372417	.0406860	.0424116	.0457597	.0479540	24
25	.0359819	.0373249	.0407682	.0425009	.0458467	.0480496	25
26	.0360593	.0374082	.0408504	.0425903	.0459338	.0481453	26
27	.0361367	.0374915	.0409328	.0426798	.0460210	.0482411	27
28	.0362142	.0375750	.0410152	.0427694	.0461083	.0483370	28
29	.0362919	.0376585	.0410977	.0428591	.0461956	.0484330	29
30	0.0363695	0.0377422	0.0411803	0.0429489	0.0462830	0.0485291	30
31	.0364473	.0378260	.0412629	.0430388	.0463706	.0486253	31
32	.0365252	.0379098	.0413457	.0431289	.0464582	.0487217	32
33	.0366031	.0379938	.0414285	.0432190	.0465458	.0488181	33
34	.0366811	.0380779	.0415114	.0433092	.0466336	.0489146	34
35	.0367592	.0381621	.0415944	.0433995	.0467214	.0490113	35
36	.0368374	.0382463	.0416774	.0434900	.0468093	.0491080	36
37	.0369157	.0383307	.0417606	.0435805	.0468973	.0492049	37
38	.0369940	.0384152	.0418438	.0436712	.0469854	.0493019	38
39	.0370725	.0384998	.0419271	.0437619	.0470736	.0493989	39
40	0.0371510	0.0385844	0.0420105	0.0438528	0.0471618	0.0494961	40
41	.0372296	.0386692	.0420940	.0439437	.0472501	.0495934	41
42	.0373083	.0387541	.0421775	.0440348	.0473385	.0496908	42
43	.0373870	.0388391	.0422611	.0441259	.0474270	.0497883	43
44	.0374658	.0389242	.0423448	.0442172	.0475156	.0498859	44
45	.0375448	.0390094	.0424286	.0443086	.0476042	.0499836	45
46	.0376238	.0390947	.0425125	.0444001	.0476929	.0500815	46
47	.0377028	.0391800	.0425965	.0444917	.0477817	.0501794	47
48	.0377820	.0392655	.0426805	.0445833	.0478706	.0502774	48
49	.0378613	.0393511	.0427646	.0446751	.0479596	.0503756	49
50	0.0379406	0.0394368	0.0428488	0.0447670	0.0480486	0.0504738	50
51	.0380200	.0395226	.0429331	.0448590	.0481377	.0505722	51
52	.0380995	.0396085	.0430175	.0449511	.0482269	.0506706	52
53	.0381790	.0396945	.0431019	.0450433	.0483162	.0507692	53
54	.0382587	.0397806	.0431864	.0451357	.0484056	.0508679	54
55	.0383384	.0398669	.0432710	.0452281	.0484950	.0509667	55
56	.0384182	.0399532	.0433557	.0453206	.0485846	.0510656	56
57	.0384981	.0400396	.0434405	.0454132	.0486742	.0511646	57
58	.0385781	.0401261	.0435253	.0455060	.0487639	.0512637	58
59	.0386582	.0402127	.0436102	.0455988	.0488536	.0513629	59
60	0.0387383	0.0402994	0.0436952	0.0456918	0.0489435	0.0514622	60

	18°		19°		20°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0489435	0.0514622	0.0544814	0.0576207	0.0603074	0.0641778	0
1	.0490334	.0515617	.0545762	.0577267	.0604069	.0642905	1
2	.0491234	.0516612	.0546710	.0578328	.0605065	.0644033	2
3	.0492135	.0517608	.0547659	.0579390	.0606062	.0645163	3
4	.0493037	.0518606	.0548609	.0580453	.0607060	.0646294	4
5	.0493939	.0519605	.0549559	.0581517	.0608058	.0647425	5
6	.0494843	.0520604	.0550511	.0582583	.0609057	.0648558	6
7	.0495747	.0521605	.0551463	.0583649	.0610058	.0649693	7
8	.0496652	.0522607	.0552416	.0584717	.0611058	.0650828	8
9	.0497557	.0523610	.0553370	.0585786	.0612060	.0651964	9
10	0.0498464	0.0524614	0.0554325	0.0586855	0.0613062	0.0653102	10
11	.0499371	.0525619	.0555280	.0587926	.0614066	.0654240	11
12	.0500279	.0526625	.0556236	.0588999	.0615070	.0655380	12
13	.0501188	.0527633	.0557193	.0590072	.0616075	.0656521	13
14	.0502098	.0528641	.0558151	.0591146	.0617080	.0657663	14
15	.0503009	.0529651	.0559110	.0592221	.0618087	.0658807	15
16	.0503920	.0530661	.0560069	.0593298	.0619094	.0659951	16
17	.0504832	.0531673	.0561029	.0594376	.0620102	.0661097	17
18	.0505745	.0532683	.0561990	.0595454	.0621111	.0662243	18
19	.0506659	.0533699	.0562952	.0596534	.0622120	.0663391	19
20	0.0507574	0.0534714	0.0563915	0.0597615	0.0623131	0.0664540	20
21	.0508489	.0535730	.0564878	.0598697	.0624142	.0665690	21
22	.0509405	.0536747	.0565843	.0599781	.0625154	.0666842	22
23	.0510322	.0537765	.0566808	.0600865	.0626167	.0667994	23
24	.0511240	.0538783	.0567773	.0601951	.0627180	.0669148	24
25	.0512158	.0539805	.0568740	.0603037	.0628194	.0670302	25
26	.0513078	.0540823	.0569707	.0604125	.0629210	.0671458	26
27	.0513998	.0541849	.0570676	.0605214	.0630226	.0672615	27
28	.0514919	.0542873	.0571645	.0606304	.0631242	.0673774	28
29	.0515841	.0543897	.0572614	.0607395	.0632260	.0674933	29
30	0.0516763	0.0544923	0.0573585	0.0608487	0.0633278	0.0676094	30
31	.0517687	.0545950	.0574556	.0609580	.0634297	.0677255	31
32	.0518611	.0546978	.0575529	.0610675	.0635317	.0678418	32
33	.0519536	.0548007	.0576502	.0611770	.0636338	.0679582	33
34	.0520462	.0549037	.0577475	.0612867	.0637359	.0680747	34
35	.0521388	.0550068	.0578450	.0613965	.0638382	.0681914	35
36	.0522316	.0551101	.0579425	.0615064	.0639405	.0683081	36
37	.0523244	.0552134	.0580402	.0616164	.0640429	.0684250	37
38	.0524173	.0553169	.0581379	.0617265	.0641453	.0685420	38
39	.0525103	.0554204	.0582356	.0618367	.0642479	.0686591	39
40	0.0526034	0.0555241	0.0583335	0.0619471	0.0643505	0.0687763	40
41	.0526965	.0556279	.0584314	.0620575	.0644532	.0688936	41
42	.0527897	.0557318	.0585295	.0621681	.0645560	.0690110	42
43	.0528830	.0558358	.0586276	.0622788	.0646588	.0691286	43
44	.0529764	.0559399	.0587257	.0623896	.0647618	.0692463	44
45	.0530699	.0560441	.0588240	.0625005	.0648648	.0693641	45
46	.0531634	.0561485	.0589223	.0626115	.0649679	.0694820	46
47	.0532570	.0562529	.0590207	.0627227	.0650711	.0696000	47
48	.0533507	.0563575	.0591192	.0628339	.0651743	.0697182	48
49	.0534445	.0564621	.0592178	.0629453	.0652777	.0698364	49
50	0.0535384	0.0565669	0.0593165	0.0630568	0.0653811	0.0699548	50
51	.0536323	.0566718	.0594152	.0631684	.0654846	.0700733	51
52	.0537264	.0567768	.0595140	.0632801	.0655881	.0701919	52
53	.0538205	.0568819	.0596129	.0633919	.0656918	.0703106	53
54	.0539146	.0569871	.0597119	.0635038	.0657955	.0704295	54
55	.0540089	.0570924	.0598109	.0636158	.0658993	.0705484	55
56	.0541032	.0571978	.0599101	.0637280	.0660032	.0706675	56
57	.0541977	.0573034	.0600093	.0638403	.0661072	.0707867	57
58	.0542922	.0574090	.0601086	.0639527	.0662112	.0709060	58
59	.0543868	.0575148	.0602079	.0640652	.0663154	.0710254	59
60	0.0544814	0.0576207	0.0603074	0.0641778	0.0664196	0.0711450	60

	21°		22°		23°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0664196	0.0711450	0.0728161	0.0785347	0.0794951	0.0863604	0
1	.0665239	.0712647	.0729252	.0786616	.0796088	.0864946	1
2	.0666282	.0713844	.0730342	.0787885	.0797226	.0866289	2
3	.0667327	.0715043	.0731434	.0789156	.0798365	.0867634	3
4	.0668372	.0716244	.0732526	.0790427	.0799504	.0868979	4
5	.0669418	.0717445	.0733620	.0791700	.0800644	.0870326	5
6	.0670465	.0718647	.0734714	.0792975	.0801785	.0871675	6
7	.0671512	.0719851	.0735808	.0794250	.0802927	.0873024	7
8	.0672561	.0721056	.0736904	.0795527	.0804069	.0874375	8
9	.0673610	.0722262	.0738000	.0796805	.0805212	.0875727	9
10	0.0674660	0.0723469	0.0739098	0.0798084	0.0806356	0.0877080	10
11	.0675710	.0724678	.0740195	.0799364	.0807501	.0878435	11
12	.0676762	.0725887	.0741294	.0800646	.0808647	.0879791	12
13	.0677814	.0727098	.0742394	.0801928	.0809793	.0881148	13
14	.0678867	.0728310	.0743494	.0803212	.0810940	.0882506	14
15	.0679921	.0729523	.0744595	.0804497	.0812088	.0883866	15
16	.0680976	.0730737	.0745697	.0805784	.0813237	.0885226	16
17	.0682031	.0731953	.0746799	.0807071	.0814386	.0886589	17
18	.0683088	.0733170	.0747903	.0808360	.0815536	.0887952	18
19	.0684145	.0734388	.0749007	.0809650	.0816687	.0889317	19
20	0.0685203	0.0735607	0.0750112	0.0810942	0.0817839	0.0890682	20
21	.0686261	.0736827	.0751218	.0812234	.0818991	.0892050	21
22	.0687321	.0738048	.0752324	.0813528	.0820145	.0893418	22
23	.0688381	.0739271	.0753432	.0814823	.0821299	.0894788	23
24	.0689442	.0740495	.0754540	.0816119	.0822454	.0896159	24
25	.0690504	.0741720	.0755649	.0817417	.0823609	.0897531	25
26	.0691566	.0742946	.0756758	.0818715	.0824766	.0898904	26
27	.0692630	.0744173	.0757869	.0820015	.0825923	.0900279	27
28	.0693694	.0745402	.0758980	.0821316	.0827081	.0901655	28
29	.0694759	.0746631	.0760092	.0822618	.0828240	.0903032	29
30	0.0695824	0.0747862	0.0761205	0.0823922	0.0829399	0.0904411	30
31	.0696891	.0749095	.0762318	.0825227	.0830560	.0905791	31
32	.0697958	.0750328	.0763433	.0826533	.0831721	.0907172	32
33	.0699026	.0751562	.0764548	.0827840	.0832882	.0908554	33
34	.0700095	.0752798	.0765664	.0829149	.0834045	.0909938	34
35	.0701165	.0754035	.0766780	.0830458	.0835209	.0911323	35
36	.0702235	.0755273	.0767898	.0831769	.0836373	.0912709	36
37	.0703306	.0756512	.0769016	.0833081	.0837538	.0914097	37
38	.0704378	.0757753	.0770135	.0834395	.0838703	.0915485	38
39	.0705451	.0758995	.0771255	.0835709	.0839870	.0916876	39
40	0.0706525	0.0760237	0.0772376	0.0837025	0.0841037	0.0918267	40
41	.0707599	.0761481	.0773497	.0838342	.0842205	.0919659	41
42	.0708674	.0762727	.0774619	.0839661	.0843374	.0921053	42
43	.0709750	.0763973	.0775742	.0840980	.0844544	.0922448	43
44	.0710827	.0765221	.0776866	.0842301	.0845714	.0923845	44
45	.0711904	.0766470	.0777990	.0843623	.0846885	.0925243	45
46	.0712983	.0767720	.0779116	.0844947	.0848057	.0926642	46
47	.0714062	.0768971	.0780242	.0846271	.0849230	.0928042	47
48	.0715142	.0770224	.0781368	.0847597	.0850403	.0929444	48
49	.0716222	.0771477	.0782496	.0848924	.0851578	.0930846	49
50	0.0717304	0.0772732	0.0783625	0.0850252	0.0852753	0.0932251	50
51	.0718386	.0773988	.0784754	.0851582	.0853928	.0933656	51
52	.0719469	.0775246	.0785884	.0852913	.0855105	.0935063	52
53	.0720553	.0776504	.0787014	.0854245	.0856282	.0936471	53
54	.0721637	.0777764	.0788146	.0855578	.0857460	.0937880	54
55	.0722723	.0779025	.0789278	.0856912	.0858639	.0939291	55
56	.0723809	.0780287	.0790411	.0858248	.0859819	.0940702	56
57	.0724896	.0781550	.0791545	.0859585	.0860999	.0942116	57
58	.0725984	.0782815	.0792680	.0860924	.0862181	.0943530	58
59	.0727072	.0784080	.0793815	.0862263	.0863363	.0944946	59
60	0.0728161	0.0785347	0.0794951	0.0863604	0.0864545	0.0946363	60

	24°		25°		26°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.0864545	0.0946363	0.0936922	0.1033779	0.1012060	0.1126019	0
1	.0865729	.0947781	.0938152	.1035277	.1013335	.1127599	1
2	.0866913	.0949201	.0939382	.1036775	.1014611	.1129179	2
3	.0868098	.0950622	.0940614	.1038275	.1015888	.1130761	3
4	.0869284	.0952044	.0941846	.1039777	.1017166	.1132345	4
5	.0870471	.0953467	.0943078	.1041279	.1018445	.1133929	5
6	.0871658	.0954892	.0944312	.1042783	.1019724	.1135516	6
7	.0872846	.0956318	.0945546	.1044289	.1021004	.1137103	7
8	.0874035	.0957746	.0946781	.1045795	.1022285	.1138692	8
9	.0875225	.0959174	.0948017	.1047303	.1023567	.1140282	9
10	0.0876416	0.0960604	0.0949254	0.1048813	0.1024849	0.1141874	10
11	.0877607	.0962036	.0950491	.1050324	.1026132	.1143467	11
12	.0878799	.0963468	.0951729	.1051836	.1027416	.1145062	12
13	.0879992	.0964902	.0952968	.1053349	.1028701	.1146658	13
14	.0881185	.0966337	.0954208	.1054864	.1029986	.1148255	14
15	.0882380	.0967774	.0955449	.1056380	.1031273	.1149854	15
16	.0883575	.0969212	.0956690	.1057898	.1032560	.1151454	16
17	.0884771	.0970651	.0957932	.1059417	.1033847	.1153056	17
18	.0885967	.0972091	.0959175	.1060937	.1035136	.1154659	18
19	.0887165	.0973533	.0960418	.1062458	.1036425	.1156263	19
20	0.0888363	0.0974976	0.0961662	0.1063981	0.1037715	0.1157869	20
21	.0889562	.0976420	.0962907	.1065506	.1039006	.1159476	21
22	.0890762	.0977866	.0964153	.1067031	.1040297	.1161084	22
23	.0891962	.0979313	.0965400	.1068558	.1041589	.1162694	23
24	.0893163	.0980761	.0966647	.1070087	.1042882	.1164306	24
25	.0894365	.0982211	.0967895	.1071616	.1044176	.1165919	25
26	.0895568	.0983662	.0969144	.1073147	.1045471	.1167533	26
27	.0896772	.0985114	.0970394	.1074680	.1046766	.1169148	27
28	.0897976	.0986568	.0971644	.1076214	.1048062	.1170766	28
29	.0899181	.0988023	.0972895	.1077749	.1049359	.1172384	29
30	0.0900387	0.0989479	0.0974147	0.1079285	0.1050656	0.1174004	30
31	.0901594	.0990936	.0975400	.1080823	.1051955	.1175625	31
32	.0902801	.0992395	.0976653	.1082363	.1053254	.1177248	32
33	.0904010	.0993855	.0977908	.1083903	.1054554	.1178872	33
34	.0905219	.0995317	.0979162	.1085445	.1055854	.1180498	34
35	.0906428	.0996779	.0980418	.1086989	.1057156	.1182124	35
36	.0907639	.0998243	.0981675	.1088533	.1058458	.1183753	36
37	.0908850	.0999709	.0982932	.1090079	.1059760	.1185383	37
38	.0910062	.1001175	.0984190	.1091627	.1061064	.1187014	38
39	.0911275	.1002644	.0985449	.1093176	.1062368	.1188647	39
40	0.0912489	0.1004113	0.0986708	0.1094726	0.1063674	0.1190281	40
41	.0913703	.1005584	.0987969	.1096277	.1064979	.1191916	41
42	.0914918	.1007056	.0989230	.1097830	.1066286	.1193553	42
43	.0916134	.1008529	.0990492	.1099385	.1067594	.1195191	43
44	.0917351	.1010004	.0991754	.1100940	.1068902	.1196831	44
45	.0918568	.1011480	.0993018	.1102498	.1070211	.1198472	45
46	.0919786	.1012957	.0994282	.1104056	.1071520	.1200115	46
47	.0921005	.1014436	.0995547	.1105616	.1072831	.1201759	47
48	.0922225	.1015916	.0996812	.1107177	.1074142	.1203405	48
49	.0923446	.1017397	.0998079	.1108740	.1075454	.1205051	49
50	0.0924667	0.1018879	0.0999346	0.1110304	0.1076766	0.1206700	50
51	.0925889	.1020363	.1000614	.1111869	.1078080	.1208350	51
52	.0927112	.1021849	.1001883	.1113436	.1079394	.1210001	52
53	.0928335	.1023335	.1003152	.1115004	.1080709	.1211653	53
54	.0929560	.1024823	.1004422	.1116573	.1082025	.1213308	54
55	.0930785	.1026313	.1005693	.1118144	.1083341	.1214963	55
56	.0932011	.1027803	.1006965	.1119716	.1084658	.1216620	56
57	.0933238	.1029295	.1008237	.1121290	.1085976	.1218278	57
58	.0934465	.1030789	.1009511	.1122865	.1087295	.1219938	58
59	.0935693	.1032283	.1010785	.1124442	.1088615	.1221600	59
60	0.0936922	0.1033779	0.1012060	0.1126019	0.1089935	0.1223262	60

	27°		28°		29°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.1089935	0.1223262	0.1170524	0.1325701	0.1253803	0.1433541	0
1	.1091256	.1224927	.1171890	.1327453	.1255214	.1435385	1
2	.1092577	.1226592	.1173257	.1329207	.1256625	.1437231	2
3	.1093900	.1228259	.1174624	.1330962	.1258037	.1439078	3
4	.1095223	.1229928	.1175993	.1332719	.1259450	.1440927	4
5	.1096547	.1231598	.1177362	.1334478	.1260863	.1442778	5
6	.1097872	.1233269	.1178731	.1336238	.1262278	.1444630	6
7	.1099197	.1234942	.1180102	.1337999	.1263693	.1446484	7
8	.1100524	.1236616	.1181473	.1339762	.1265109	.1448339	8
9	.1101851	.1238292	.1182845	.1341527	.1266525	.1450196	9
10	0.1103178	0.1239969	0.1184218	0.1343293	0.1267942	0.1452055	10
11	.1104507	.1241648	.1185591	.1345060	.1269360	.1453915	11
12	.1105836	.1243328	.1186965	.1346829	.1270779	.1455776	12
13	.1107166	.1245010	.1188340	.1348600	.1272199	.1457639	13
14	.1108497	.1246693	.1189716	.1350372	.1273619	.1459504	14
15	.1109829	.1248377	.1191093	.1352146	.1275040	.1461371	15
16	.1111161	.1250063	.1192470	.1353921	.1276462	.1463238	16
17	.1112494	.1251750	.1193848	.1355697	.1277884	.1465108	17
18	.1113828	.1253439	.1195226	.1357476	.1279307	.1466979	18
19	.1115162	.1255130	.1196606	.1359255	.1280731	.1468852	19
20	0.1116497	0.1256821	0.1197983	0.1361036	0.1282156	0.1470726	20
21	.1117834	.1258514	.1199367	.1362819	.1283581	.1472602	21
22	.1119170	.1260209	.1200749	.1364603	.1285007	.1474479	22
23	.1120508	.1261905	.1202131	.1366389	.1286434	.1476358	23
24	.1121846	.1263603	.1203514	.1368176	.1287862	.1478239	24
25	.1123185	.1265302	.1204898	.1369965	.1289290	.1480121	25
26	.1124525	.1267003	.1206283	.1371755	.1290719	.1482005	26
27	.1125866	.1268705	.1207668	.1373547	.1292149	.1483890	27
28	.1127207	.1270408	.1209054	.1375341	.1293580	.1485777	28
29	.1128549	.1272113	.1210441	.1377135	.1295011	.1487665	29
30	0.1129892	0.1273819	0.1211829	0.1378932	0.1296443	0.1489555	30
31	.1131235	.1275527	.1213217	.1380730	.1297876	.1491447	31
32	.1132580	.1277237	.1214606	.1382529	.1299309	.1493340	32
33	.1133925	.1278948	.1215996	.1384330	.1300744	.1495235	33
34	.1135270	.1280660	.1217387	.1386133	.1302179	.1497132	34
35	.1136617	.1282374	.1218778	.1387937	.1303614	.1499030	35
36	.1137964	.1284089	.1220170	.1389742	.1305051	.1500930	36
37	.1139312	.1285806	.1221563	.1391550	.1306488	.1502831	37
38	.1140661	.1287524	.1222957	.1393358	.1307926	.1504734	38
39	.1142011	.1289244	.1224351	.1395169	.1309364	.1506638	39
40	0.1143361	0.1290965	0.1225746	0.1396980	0.1310804	0.1508544	40
41	.1144712	.1292687	.1227142	.1398794	.1312244	.1510452	41
42	.1146064	.1294412	.1228538	.1400608	.1313685	.1512361	42
43	.1147416	.1296137	.1229936	.1402425	.1315126	.1514272	43
44	.1148770	.1297864	.1231334	.1404243	.1316569	.1516185	44
45	.1150124	.1299593	.1232732	.1406062	.1318012	.1518099	45
46	.1151478	.1301323	.1234132	.1407883	.1319456	.1520015	46
47	.1152834	.1303055	.1235532	.1409706	.1320900	.1521932	47
48	.1154190	.1304788	.1236933	.1411530	.1322345	.1523851	48
49	.1155547	.1306522	.1238335	.1413356	.1323791	.1525772	49
50	0.1156905	0.1308258	0.1239737	0.1415183	0.1325238	0.1527694	50
51	.1158264	.1309996	.1241141	.1417012	.1326686	.1529618	51
52	.1159623	.1311735	.1242545	.1418842	.1328134	.1531543	52
53	.1160983	.1313475	.1243949	.1420674	.1329583	.1533470	53
54	.1162344	.1315217	.1245355	.1422507	.1331033	.1535399	54
55	.1163705	.1316961	.1246761	.1424342	.1332483	.1537329	55
56	.1165067	.1318706	.1248168	.1426179	.1333934	.1539261	56
57	.1166431	.1320452	.1249575	.1428017	.1335386	.1541195	57
58	.1167794	.1322200	.1250984	.1429857	.1336839	.1543130	58
59	.1169159	.1323950	.1252393	.1431698	.1338292	.1545067	59
60	0.1170524	0.1325701	0.1253803	0.1433541	0.1339746	0.1547005	60

	30°		31°		32°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.1339746	0.1547005	0.1428327	0.1666334	0.1519519	0.1791784	0
1	.1341201	.1548945	.1429826	.1668374	.1521061	.1793928	1
2	.1342656	.1550887	.1431325	.1670416	.1522603	.1796074	2
3	.1344113	.1552830	.1432825	.1672459	.1524147	.1798222	3
4	.1345570	.1554775	.1434326	.1674504	.1525691	.1800372	4
5	.1347027	.1556722	.1435827	.1676551	.1527235	.1802523	5
6	.1348486	.1558670	.1437329	.1678599	.1528781	.1804676	6
7	.1349945	.1560620	.1438832	.1680649	.1530327	.1806831	7
8	.1351405	.1562572	.1440336	.1682701	.1531874	.1808988	8
9	.1352866	.1564525	.1441840	.1684755	.1533421	.1811146	9
10	0.1354327	0.1566480	0.1443345	0.1686810	0.1534970	0.1813307	10
11	.1355789	.1568436	.1444851	.1688867	.1536519	.1815469	11
12	.1357252	.1570394	.1446357	.1690926	.1538068	.1817633	12
13	.1358716	.1572354	.1447865	.1692986	.1539619	.1819798	13
14	.1360180	.1574315	.1449373	.1695048	.1541170	.1821966	14
15	.1361645	.1576278	.1450881	.1697112	.1542722	.1824135	15
16	.1363111	.1578243	.1452391	.1699178	.1544274	.1826306	16
17	.1364577	.1580209	.1453901	.1701245	.1545828	.1828479	17
18	.1366044	.1582177	.1455412	.1703314	.1547382	.1830654	18
19	.1367512	.1584146	.1456923	.1705385	.1548936	.1832830	19
20	0.1368981	0.1586118	0.1458436	0.1707457	0.1550492	0.1835008	20
21	.1370451	.1588091	.1459949	.1709531	.1552048	.1837188	21
22	.1371921	.1590065	.1461462	.1711607	.1553605	.1839370	22
23	.1373392	.1592041	.1462977	.1713685	.1555162	.1841554	23
24	.1374863	.1594019	.1464492	.1715764	.1556721	.1843739	24
25	.1376336	.1595999	.1466008	.1717845	.1558280	.1845927	25
26	.1377809	.1597980	.1467525	.1719928	.1559839	.1848116	26
27	.1379283	.1599963	.1469042	.1722013	.1561400	.1850307	27
28	.1380757	.1601947	.1470560	.1724099	.1562961	.1852500	28
29	.1382232	.1603933	.1472079	.1726187	.1564523	.1854694	29
30	0.1383708	0.1605921	0.1473598	0.1728277	0.1566086	0.1856890	30
31	.1385185	.1607911	.1475119	.1730368	.1567649	.1859089	31
32	.1386663	.1609902	.1476640	.1732462	.1569213	.1861289	32
33	.1388141	.1611894	.1478161	.1734557	.1570778	.1863490	33
34	.1389620	.1613889	.1479684	.1736653	.1572343	.1865694	34
35	.1391099	.1615885	.1481207	.1738752	.1573909	.1867900	35
36	.1392580	.1617883	.1482731	.1740852	.1575476	.1870107	36
37	.1394061	.1619882	.1484255	.1742954	.1577044	.1872316	37
38	.1395543	.1621883	.1485781	.1745058	.1578612	.1874527	38
39	.1397025	.1623886	.1487307	.1747163	.1580181	.1876740	39
40	0.1398509	0.1625891	0.1488833	0.1749270	0.1581751	0.1878954	40
41	.1399993	.1627897	.1490361	.1751379	.1583321	.1881171	41
42	.1401477	.1629905	.1491889	.1753490	.1584892	.1883389	42
43	.1402963	.1631914	.1493418	.1755603	.1586464	.1885609	43
44	.1404449	.1633925	.1494947	.1757717	.1588037	.1887831	44
45	.1405936	.1635938	.1496478	.1759833	.1589610	.1890055	45
46	.1407424	.1637953	.1498009	.1761951	.1591184	.1892280	46
47	.1408912	.1639969	.1499541	.1764070	.1592759	.1894508	47
48	.1410401	.1641987	.1501073	.1766191	.1594334	.1896737	48
49	.1411891	.1644007	.1502603	.1768314	.1595910	.1898968	49
50	0.1413381	0.1646028	0.1504140	0.1770439	0.1597487	0.1901201	50
51	.1414873	.1648051	.1505675	.1772566	.1599064	.1903436	51
52	.1416365	.1650076	.1507210	.1774694	.1600643	.1905673	52
53	.1417857	.1652102	.1508746	.1776824	.1602222	.1907911	53
54	.1419351	.1654130	.1510283	.1778956	.1603801	.1910152	54
55	.1420845	.1656160	.1511821	.1781089	.1605382	.1912394	55
56	.1422340	.1658191	.1513359	.1783225	.1606963	.1914638	56
57	.1423836	.1660224	.1514898	.1785362	.1608545	.1916884	57
58	.1425332	.1662259	.1516438	.1787501	.1610127	.1919132	58
59	.1426829	.1664296	.1517978	.1789642	.1611710	.1921381	59
60	0.1428327	0.1666334	0.1519519	0.1791784	0.1613294	0.1923633	60

	33°		34°		35°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.1613294	0.1923633	0.1709624	0.2062179	0.1808480	0.2207746	0
1	.1614879	.1925886	.1711251	.2064547	.1810148	.2210233	1
2	.1616464	.1928142	.1712879	.2066917	.1811818	.2212723	2
3	.1618050	.1930399	.1714507	.2069288	.1813488	.2215215	3
4	.1619637	.1932658	.1716136	.2071662	.1815159	.2217708	4
5	.1621225	.1934918	.1717766	.2074037	.1816831	.2220204	5
6	.1622813	.1937181	.1719397	.2076415	.1818503	.2222702	6
7	.1624402	.1939446	.1721028	.2078794	.1820176	.2225202	7
8	.1625991	.1941712	.1722660	.2081175	.1821849	.2227703	8
9	.1627582	.1943980	.1724292	.2083559	.1823524	.2230207	9
10	0.1629173	0.1946251	0.1725926	0.2085944	0.1825199	0.2232713	10
11	.1630764	.1948523	.1727560	.2088331	.1826875	.2235222	11
12	.1632357	.1950796	.1729194	.2090720	.1828551	.2237732	12
13	.1633950	.1953072	.1730830	.2093112	.1830228	.2240244	13
14	.1635544	.1955350	.1732466	.2095505	.1831906	.2242758	14
15	.1637138	.1957629	.1734103	.2097900	.1833584	.2245274	15
16	.1638734	.1959911	.1735740	.2100297	.1835264	.2247793	16
17	.1640330	.1962194	.1737378	.2102696	.1836944	.2250313	17
18	.1641926	.1964479	.1739017	.2105097	.1838624	.2252836	18
19	.1643524	.1966767	.1740657	.2107500	.1840305	.2255361	19
20	0.1645122	0.1969056	0.1742297	0.2109905	0.1841987	0.2257887	20
21	.1646721	.1971346	.1743938	.2112312	.1843670	.2260416	21
22	.1648320	.1973639	.1745580	.2114721	.1845353	.2262947	22
23	.1649920	.1975934	.1747222	.2117132	.1847037	.2265480	23
24	.1651521	.1978230	.1748865	.2119545	.1848722	.2268011	24
25	.1653123	.1980529	.1750509	.2121960	.1850407	.2270552	25
26	.1654725	.1982829	.1752153	.2124377	.1852094	.2273091	26
27	.1656328	.1985131	.1753798	.2126795	.1853780	.2275633	27
28	.1657932	.1987435	.1755444	.2129216	.1855468	.2278176	28
29	.1659537	.1989741	.1757091	.2131639	.1857156	.2280722	29
30	0.1661142	0.1992049	0.1758738	0.2134064	0.1858845	0.2283269	30
31	.1662748	.1994359	.1760386	.2136491	.1860534	.2285819	31
32	.1664354	.1996671	.1762035	.2138920	.1862225	.2288371	32
33	.1665962	.1998985	.1763684	.2141351	.1863916	.2290924	33
34	.1667570	.2001300	.1765334	.2143784	.1865607	.2293480	34
35	.1669178	.2003618	.1766985	.2146218	.1867299	.2296039	35
36	.1670788	.2005937	.1768636	.2148655	.1868992	.2298599	36
37	.1672398	.2008258	.1770288	.2151094	.1870686	.2301161	37
38	.1674009	.2010582	.1771941	.2153535	.1872380	.2303725	38
39	.1675620	.2012907	.1773595	.2155978	.1874075	.2306292	39
40	0.1677232	0.2015234	0.1775249	0.2158423	0.1875771	0.2308861	40
41	.1678845	.2017563	.1776904	.2160870	.1877468	.2311432	41
42	.1680459	.2019894	.1778560	.2163319	.1879165	.2314004	42
43	.1682073	.2022226	.1780216	.2165770	.1880863	.2316579	43
44	.1683688	.2024561	.1781873	.2168223	.1882561	.2319156	44
45	.1685304	.2026898	.1783531	.2170678	.1884260	.2321736	45
46	.1686920	.2029236	.1785189	.2173135	.1885960	.2324317	46
47	.1688537	.2031577	.1786848	.2175594	.1887661	.2326900	47
48	.1690155	.2033919	.1788508	.2178055	.1889362	.2329486	48
49	.1691774	.2036264	.1790168	.2180518	.1891064	.2332074	49
50	0.1693393	0.2038610	0.1791830	0.2182983	0.1892766	0.2334664	50
51	.1695013	.2040958	.1793491	.2185450	.1894470	.2337256	51
52	.1696634	.2043308	.1795154	.2187919	.1896174	.2339850	52
53	.1698255	.2045660	.1796817	.2190390	.1897878	.2342446	53
54	.1699877	.2048014	.1798481	.2192864	.1899584	.2345044	54
55	.1701500	.2050370	.1800146	.2195339	.1901290	.2347645	55
56	.1703123	.2052728	.1801811	.2197816	.1902996	.2350248	56
57	.1704748	.2055088	.1803477	.2200296	.1904704	.2352852	57
58	.1706372	.2057450	.1805144	.2202777	.1906412	.2355459	58
59	.1707998	.2059814	.1806811	.2205260	.1908121	.2358069	59
60	0.1709624	0.2062179	0.1808480	0.2207746	0.1909830	0.2360680	60

	36°		37°		38°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.1909830	0.2360680	0.2013645	0.2521357	0.2119892	0.2690182	0
1	.1911540	.2363293	.2015396	.2524102	.2121684	.2693067	1
2	.1913251	.2365909	.2017147	.2526850	.2123476	.2695955	2
3	.1914963	.2368526	.2018900	.2529601	.2125268	.2698845	3
4	.1916675	.2371146	.2020653	.2532353	.2127061	.2701737	4
5	.1918388	.2373768	.2022406	.2535108	.2128855	.2704632	5
6	.1920101	.2376393	.2024161	.2537865	.2130650	.2707529	6
7	.1921815	.2379019	.2025916	.2540625	.2132445	.2710429	7
8	.1923530	.2381647	.2027671	.2543387	.2134241	.2713331	8
9	.1925246	.2384278	.2029428	.2546151	.2136037	.2716235	9
10	0.1926962	0.2386911	0.2031185	0.2548917	0.2137835	0.2719142	10
11	.1928679	.2389546	.2032942	.2551685	.2139633	.2722052	11
12	.1930397	.2392183	.2034701	.2554456	.2141431	.2724963	12
13	.1932115	.2394823	.2036460	.2557229	.2143230	.2727877	13
14	.1933834	.2397464	.2038220	.2560005	.2145030	.2730794	14
15	.1935554	.2400108	.2039980	.2562782	.2146831	.2733712	15
16	.1937274	.2402754	.2041741	.2565562	.2148632	.2736634	16
17	.1938995	.2405402	.2043503	.2568345	.2150434	.2739557	17
18	.1940717	.2408052	.2045265	.2571129	.2152236	.2742484	18
19	.1942440	.2410704	.2047028	.2573916	.2154039	.2745412	19
20	0.1944163	0.2413359	0.2048792	0.2576705	0.2155843	0.2748343	20
21	.1945887	.2416016	.2050556	.2579497	.2157648	.2751276	21
22	.1947611	.2418675	.2052322	.2582291	.2159453	.2754212	22
23	.1949336	.2421336	.2054087	.2585087	.2161259	.2757151	23
24	.1951062	.2423999	.2055854	.2587885	.2163065	.2760091	24
25	.1952789	.2426665	.2057621	.2590686	.2164873	.2763034	25
26	.1954516	.2429333	.2059389	.2593489	.2166680	.2765980	26
27	.1956244	.2432003	.2061157	.2596294	.2168489	.2768928	27
28	.1957972	.2434675	.2062926	.2599102	.2170298	.2771878	28
29	.1959701	.2437349	.2064696	.2601912	.2172108	.2774831	29
30	0.1961431	0.2440026	0.2066467	0.2604724	0.2173918	0.2777787	30
31	.1963162	.2442704	.2068238	.2607539	.2175730	.2780744	31
32	.1964893	.2445385	.2070010	.2610356	.2177541	.2783705	32
33	.1966625	.2448069	.2071782	.2613175	.2179354	.2786667	33
34	.1968358	.2450754	.2073555	.2615997	.2181167	.2789632	34
35	.1970091	.2453442	.2075329	.2618820	.2182981	.2792600	35
36	.1971825	.2456131	.2077104	.2621647	.2184795	.2795570	36
37	.1973560	.2458823	.2078879	.2624475	.2186610	.2798543	37
38	.1975295	.2461518	.2080655	.2627306	.2188426	.2801518	38
39	.1977031	.2464214	.2082431	.2630140	.2190243	.2804495	39
40	0.1978768	0.2466913	0.2084208	0.2632975	0.2192060	0.2807475	40
41	.1980505	.2469614	.2085986	.2635813	.2193877	.2810457	41
42	.1982244	.2472317	.2087765	.2638653	.2195696	.2813442	42
43	.1983982	.2475022	.2089544	.2641496	.2197515	.2816430	43
44	.1985722	.2477730	.2091324	.2644341	.2199335	.2819419	44
45	.1987462	.2480440	.2093104	.2647188	.2201155	.2822412	45
46	.1989203	.2483152	.2094885	.2650038	.2202976	.2825407	46
47	.1990944	.2485866	.2096667	.2652890	.2204798	.2828404	47
48	.1992686	.2488583	.2098450	.2655745	.2206620	.2831404	48
49	.1994429	.2491302	.2100233	.2658601	.2208443	.2834406	49
50	0.1996173	0.2494023	0.2102017	0.2661460	0.2210267	0.2837411	50
51	.1997917	.2496746	.2103802	.2664322	.2212091	.2840418	51
52	.1999662	.2499471	.2105587	.2667186	.2213916	.2843428	52
53	.2001407	.2502199	.2107373	.2670052	.2215742	.2846440	53
54	.2003153	.2504929	.2109159	.2672921	.2217569	.2849445	54
55	.2004900	.2507661	.2110946	.2675792	.2219396	.2852472	55
56	.2006648	.2510396	.2112734	.2678665	.2221223	.2855492	56
57	.2008396	.2513133	.2114523	.2681541	.2223051	.2858514	57
58	.2010145	.2515872	.2116312	.2684419	.2224880	.2861539	58
59	.2011895	.2518613	.2118102	.2687299	.2226710	.2864566	59
60	0.2013645	0.2521357	0.2119892	0.2690182	0.2228540	0.2867596	60

	39°		40°		41°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.2228540	0.2867596	0.2339556	0.3054073	0.2452904	0.3250130	0
1	.2230371	.2870628	.2341426	.3057261	.2454813	.3253482	1
2	.2232203	.2873663	.2343296	.3060451	.2456722	.3256837	2
3	.2234035	.2876700	.2345168	.3063644	.2458632	.3260194	3
4	.2235868	.2879740	.2347040	.3066839	.2460543	.3263554	4
5	.2237702	.2882782	.2348913	.3070038	.2462454	.3266918	5
6	.2239536	.2885827	.2350786	.3073239	.2464366	.3270284	6
7	.2241371	.2888875	.2352660	.3076442	.2466279	.3273653	7
8	.2243206	.2891925	.2354535	.3079649	.2468192	.3277024	8
9	.2245043	.2894977	.2356410	.3082858	.2470106	.3280399	9
10	0.2246879	0.2898032	0.2358286	0.3086069	0.2472020	0.3283776	10
11	.2248717	.2901090	.2360162	.3089284	.2473935	.3287156	11
12	.2250555	.2904150	.2362040	.3092501	.2475851	.3290539	12
13	.2252394	.2907213	.2363918	.3095720	.2477767	.3293925	13
14	.2254233	.2910278	.2365796	.3098943	.2479684	.3297314	14
15	.2256074	.2913346	.2367675	.3102168	.2481602	.3300706	15
16	.2257914	.2916416	.2369555	.3105396	.2483520	.3304100	16
17	.2259756	.2919489	.2371436	.3108626	.2485439	.3307497	17
18	.2261598	.2922564	.2373317	.3111860	.2487359	.3310897	18
19	.2263441	.2925642	.2375198	.3115095	.2489279	.3314301	19
20	0.2265284	0.2928723	0.2377081	0.3118334	0.2491200	0.3317707	20
21	.2267128	.2931806	.2378964	.3121575	.2493121	.3321115	21
22	.2268973	.2934892	.2380848	.3124820	.2495043	.3324527	22
23	.2270818	.2937980	.2382732	.3128066	.2496966	.3327942	23
24	.2272664	.2941071	.2384617	.3131316	.2498889	.3331359	24
25	.2274511	.2944164	.2386503	.3134568	.2500813	.3334779	25
26	.2276358	.2947260	.2388389	.3137823	.2502738	.3338203	26
27	.2278206	.2950359	.2390276	.3141081	.2504663	.3341629	27
28	.2280055	.2953460	.2392163	.3144341	.2506589	.3345058	28
29	.2281904	.2956564	.2394051	.3147604	.2508516	.3348489	29
30	0.2283754	0.2959670	0.2395940	0.3150870	0.2510443	0.3351924	30
31	.2285605	.2962779	.2397830	.3154139	.2512371	.3355362	31
32	.2287456	.2965890	.2399720	.3157410	.2514299	.3358802	32
33	.2289308	.2969004	.2401611	.3160684	.2516228	.3362246	33
34	.2291160	.2972121	.2403502	.3163961	.2518158	.3365692	34
35	.2293014	.2975240	.2405394	.3167240	.2520088	.3369141	35
36	.2294868	.2978362	.2407287	.3170523	.2522019	.3372594	36
37	.2296722	.2981487	.2409180	.3173808	.2523951	.3376049	37
38	.2298577	.2984614	.2411074	.3177096	.2525883	.3379507	38
39	.2300433	.2987743	.2412969	.3180386	.2527816	.3382968	39
40	0.2302290	0.2990876	0.2414864	0.3183680	0.2529749	0.3386432	40
41	.2304147	.2994011	.2416760	.3186976	.2531683	.3389898	41
42	.2306004	.2997148	.2418657	.3190274	.2533618	.3393368	42
43	.2307863	.3000288	.2420554	.3193576	.2535554	.3396841	43
44	.2309722	.3003431	.2422452	.3196881	.2537490	.3400316	44
45	.2311582	.3006576	.2424350	.3200188	.2539426	.3403795	45
46	.2313442	.3009724	.2426249	.3203498	.2541364	.3407276	46
47	.2315303	.3012875	.2428149	.3206810	.2543301	.3410761	47
48	.2317165	.3016028	.2430049	.3210126	.2545240	.3414248	48
49	.2319027	.3019184	.2431950	.3213444	.2547179	.3417738	49
50	0.2320890	0.3022343	0.2433852	0.3216765	0.2549119	0.3421232	50
51	.2322754	.3025504	.2435754	.3220089	.2551059	.3424728	51
52	.2324618	.3028667	.2437657	.3223416	.2553001	.3428227	52
53	.2326483	.3031834	.2439561	.3226745	.2554942	.3431729	53
54	.2328348	.3035003	.2441465	.3230078	.2556885	.3435234	54
55	.2330215	.3038175	.2443370	.3233413	.2558827	.3438742	55
56	.2332082	.3041349	.2445276	.3236750	.2560771	.3442253	56
57	.2333949	.3044526	.2447182	.3240091	.2562715	.3445767	57
58	.2335817	.3047706	.2449089	.3243435	.2564660	.3449284	58
59	.2337686	.3050888	.2450996	.3246781	.2566606	.3452804	59
60	0.2339556	0.3054073	0.2452904	0.3250130	0.2568552	0.3456327	60

	42°		43°		44°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.2568552	0.3456327	0.2686463	0.3673275	0.2806602	0.3901636	0
1	.2570498	.3459853	.2688447	.3676985	.2808623	.3905543	1
2	.2572446	.3463382	.2690432	.3680699	.2810645	.3909453	2
3	.2574394	.3466914	.2692417	.3684416	.2812667	.3913366	3
4	.2576342	.3470449	.2694403	.3688135	.2814690	.3917283	4
5	.2578292	.3473987	.2696390	.3691859	.2816713	.3921203	5
6	.2580242	.3477528	.2698377	.3695586	.2818737	.3925127	6
7	.2582192	.3481072	.2700365	.3699315	.2820762	.3929054	7
8	.2584143	.3484619	.2702354	.3703048	.2822787	.3932985	8
9	.2586095	.3488168	.2704343	.3706784	.2824813	.3936918	9
10	0.2588047	0.3491721	0.2706332	0.3710523	0.2826839	0.3940856	10
11	.2590000	.3495277	.2708323	.3714266	.2828866	.3944796	11
12	.2591954	.3498836	.2710314	.3718011	.2830894	.3948740	12
13	.2593908	.3502398	.2712305	.3721760	.2832922	.3952688	13
14	.2595863	.3505963	.2714297	.3725512	.2834951	.3956639	14
15	.2597819	.3509531	.2716290	.3729268	.2836981	.3960593	15
16	.2599775	.3513102	.2718284	.3733026	.2839011	.3964551	16
17	.2601732	.3516677	.2720278	.3736788	.2841041	.3968512	17
18	.2603689	.3520254	.2722272	.3740553	.2843073	.3972477	18
19	.2605647	.3523834	.2724268	.3744321	.2845105	.3976445	19
20	0.2607606	0.3527417	0.2726264	0.3748092	0.2847137	0.3980416	20
21	.2609565	.3531003	.2728260	.3751867	.2849170	.3984391	21
22	.2611525	.3534593	.2730257	.3755645	.2851204	.3988369	22
23	.2613485	.3538185	.2732255	.3759426	.2853238	.3992351	23
24	.2615447	.3541780	.2734253	.3763210	.2855273	.3996336	24
25	.2617408	.3545379	.2736252	.3766998	.2857309	.4000325	25
26	.2619371	.3548980	.2738252	.3770789	.2859345	.4004317	26
27	.2621334	.3552585	.2740252	.3774583	.2861382	.4008313	27
28	.2623297	.3556193	.2742253	.3778380	.2863419	.4012312	28
29	.2625262	.3559803	.2744254	.3782181	.2865457	.4016315	29
30	0.2627227	0.3563417	0.2746256	0.3785985	0.2867496	0.4020321	30
31	.2629192	.3567034	.2748259	.3789792	.2869535	.4024330	31
32	.2631158	.3570654	.2750262	.3793602	.2871574	.4028343	32
33	.2633125	.3574277	.2752266	.3797416	.2873615	.4032360	33
34	.2635092	.3577903	.2754271	.3801233	.2875656	.4036380	34
35	.2637060	.3581532	.2756276	.3805053	.2877697	.4040403	35
36	.2639029	.3585164	.2758281	.3808877	.2879740	.4044430	36
37	.2640998	.3588800	.2760288	.3812704	.2881782	.4048461	37
38	.2642968	.3592438	.2762295	.3816534	.2883826	.4052494	38
39	.2644939	.3596080	.2764302	.3820367	.2885870	.4056532	39
40	0.2646910	0.3599725	0.2766310	0.3824204	0.2887914	0.4060573	40
41	.2648882	.3603372	.2768319	.3828044	.2889959	.4064617	41
42	.2650854	.3607023	.2770329	.3831887	.2892005	.4068665	42
43	.2652827	.3610677	.2772339	.3835734	.2894052	.4072717	43
44	.2654801	.3614334	.2774349	.3839584	.2896099	.4076772	44
45	.2656775	.3617995	.2776360	.3843437	.2898146	.4080831	45
46	.2658750	.3621658	.2778372	.3847294	.2900194	.4084893	46
47	.2660725	.3625324	.2780385	.3851153	.2902243	.4088958	47
48	.2662701	.3628994	.2782398	.3855017	.2904293	.4093028	48
49	.2664678	.3632667	.2784411	.3858883	.2906343	.4097100	49
50	0.2666655	0.3636343	0.2786426	0.3862753	0.2908393	0.4101177	50
51	.2668633	.3640022	.2788441	.3866626	.2910444	.4105257	51
52	.2670612	.3643704	.2790456	.3870503	.2912496	.4109340	52
53	.2672591	.3647389	.2792472	.3874383	.2914549	.4113427	53
54	.2674571	.3651078	.2794489	.3878266	.2916602	.4117517	54
55	.2676551	.3654770	.2796506	.3882153	.2918655	.4121612	55
56	.2678533	.3658464	.2798524	.3886043	.2920709	.4125709	56
57	.2680514	.3662162	.2800543	.3889936	.2922764	.4129810	57
58	.2682497	.3665863	.2802562	.3893832	.2924820	.4133915	58
59	.2684479	.3669567	.2804582	.3897733	.2926876	.4138024	59
60	0.2686463	0.3673275	0.2806602	0.3901636	0.2928932	0.4142136	60

	45°		46°		47°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.2928932	0.4142136	0.3053416	0.4395565	0.3180016	0.4662792	0
1	.2930989	.4146251	.3055509	.4399904	.3182144	.4667368	1
2	.2933047	.4150370	.3057602	.4404246	.3184272	.4671948	2
3	.2935106	.4154493	.3059696	.4408592	.3186401	.4676532	3
4	.2937165	.4158619	.3061791	.4412941	.3188531	.4681120	4
5	.2939224	.4162749	.3063886	.4417295	.3190661	.4685713	5
6	.2941284	.4166883	.3065982	.4421652	.3192791	.4690309	6
7	.2943345	.4171020	.3068078	.4426013	.3194922	.4694910	7
8	.2945406	.4175161	.3070175	.4430379	.3197054	.4699514	8
9	.2947468	.4179306	.3072272	.4434748	.3199187	.4704123	9
10	0.2949531	0.4183454	0.3074370	0.4439120	0.3201319	0.4708736	10
11	.2951594	.4187605	.3076469	.4443497	.3203453	.4713354	11
12	.2953658	.4191761	.3078568	.4447878	.3205587	.4717975	12
13	.2955722	.4195920	.3080668	.4452262	.3207722	.4722600	13
14	.2957787	.4200082	.3082768	.4456651	.3209857	.4727230	14
15	.2959853	.4204248	.3084869	.4461043	.3211993	.4731864	15
16	.2961919	.4208418	.3086971	.4465439	.3214129	.4736502	16
17	.2963986	.4212592	.3089073	.4469839	.3216266	.4741144	17
18	.2966053	.4216769	.3091176	.4474243	.3218403	.4745790	18
19	.2968121	.4220950	.3093279	.4478651	.3220541	.4750440	19
20	0.2970189	0.4225134	0.3095383	0.4483063	0.3222680	0.4755095	20
21	.2972259	.4229323	.3097488	.4487478	.3224819	.4759754	21
22	.2974328	.4233514	.3099593	.4491898	.3226959	.4764417	22
23	.2976399	.4237710	.3101698	.4496322	.3229099	.4769084	23
24	.2978469	.4241909	.3103805	.4500749	.3231240	.4773755	24
25	.2980541	.4246112	.3105911	.4505181	.3233382	.4778431	25
26	.2982613	.4250319	.3108019	.4509616	.3235524	.4783111	26
27	.2984686	.4254529	.3110127	.4514055	.3237667	.4787795	27
28	.2986759	.4258743	.3112235	.4518498	.3239810	.4792483	28
29	.2988833	.4262961	.3114345	.4522946	.3241954	.4797176	29
30	0.2990907	0.4267182	0.3116454	0.4527397	0.3244098	0.4801872	30
31	.2992982	.4271407	.3118565	.4531852	.3246243	.4806573	31
32	.2995058	.4275636	.3120675	.4536311	.3248388	.4811278	32
33	.2997134	.4279868	.3122787	.4540774	.3250534	.4815988	33
34	.2999211	.4284105	.3124899	.4545241	.3252681	.4820702	34
35	.3001289	.4288345	.3127012	.4549712	.3254828	.4825420	35
36	.3003367	.4292588	.3129125	.4554187	.3256976	.4830142	36
37	.3005445	.4296836	.3131239	.4558666	.3259124	.4834868	37
38	.3007524	.4301087	.3133353	.4563149	.3261273	.4839599	38
39	.3009604	.4305342	.3135468	.4567636	.3263423	.4844334	39
40	0.3011685	0.4309600	0.3137584	0.4572127	0.3265573	0.4849073	40
41	.3013766	.4313863	.3139700	.4576621	.3267724	.4853817	41
42	.3015847	.4318129	.3141816	.4581120	.3269875	.4858565	42
43	.3017929	.4322399	.3143934	.4585623	.3272027	.4863317	43
44	.3020012	.4326672	.3146052	.4590130	.3274179	.4868073	44
45	.3022095	.4330950	.3148170	.4594641	.3276332	.4872834	45
46	.3024179	.4335231	.3150289	.4599156	.3278485	.4877599	46
47	.3026264	.4339516	.3152409	.4603675	.3280639	.4882369	47
48	.3028349	.4343805	.3154529	.4608198	.3282794	.4887142	48
49	.3030435	.4348097	.3156650	.4612726	.3284949	.4891920	49
50	0.3032521	0.4352393	0.3158771	0.4617257	0.3287105	0.4896703	50
51	.3034608	.4356693	.3160893	.4621792	.3289261	.4901489	51
52	.3036695	.4360997	.3163016	.4626331	.3291418	.4906280	52
53	.3038783	.4365305	.3165139	.4630875	.3293576	.4911076	53
54	.3040872	.4369616	.3167262	.4635422	.3295734	.4915876	54
55	.3042961	.4373932	.3169387	.4639973	.3297892	.4920680	55
56	.3045051	.4378251	.3171511	.4644529	.3300052	.4925488	56
57	.3047142	.4382574	.3173637	.4649089	.3302211	.4930301	57
58	.3049233	.4386900	.3175763	.4653652	.3304372	.4935118	58
59	.3051324	.4391231	.3177889	.4658220	.3306532	.4939940	59
60	0.3053416	0.4395565	0.3180016	0.4662792	0.3308694	0.4944765	60

	48°		49°		50°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.3308694	0.4944765	0.3439410	0.5242531	0.3572124	0.5557238	0
1	.3310856	.4949596	.3441605	.5247634	.3574353	.5562634	1
2	.3313019	.4954431	.3443802	.5252741	.3576582	.5568035	2
3	.3315182	.4959270	.3445998	.5257854	.3578811	.5573441	3
4	.3317345	.4964113	.3448196	.5262971	.3581042	.5578852	4
5	.3319510	.4968961	.3450393	.5268093	.3583272	.5584268	5
6	.3321674	.4973813	.3452592	.5273219	.3585504	.5589689	6
7	.3323840	.4978670	.3454791	.5278351	.3587736	.5595115	7
8	.3326006	.4983531	.3456990	.5283487	.3589968	.5600546	8
9	.3328172	.4988397	.3459190	.5288627	.3592201	.5605982	9
10	0.3330339	0.4993267	0.3461391	0.5293773	0.3594434	0.5611424	10
11	.3332507	.4998141	.3463592	.5298923	.3596668	.5616871	11
12	.3334675	.5003020	.3465794	.5304078	.3598903	.5622322	12
13	.3336844	.5007903	.3467996	.5309238	.3601138	.5627779	13
14	.3339013	.5012791	.3470199	.5314403	.3603374	.5633241	14
15	.3341183	.5017683	.3472402	.5319572	.3605610	.5638708	15
16	.3343354	.5022580	.3474606	.5324746	.3607847	.5644181	16
17	.3345525	.5027481	.3476811	.5329925	.3610084	.5649658	17
18	.3347696	.5032387	.3479016	.5335109	.3612322	.5655141	18
19	.3349869	.5037297	.3481222	.5340297	.3614560	.5660628	19
20	0.3352041	0.5042211	0.3483428	0.5345491	0.3616799	0.5666121	20
21	.3354215	.5047131	.3485634	.5350689	.3619039	.5671619	21
22	.3356388	.5052054	.3487842	.5355892	.3621279	.5677123	22
23	.3358563	.5056982	.3490049	.5361100	.3623519	.5682631	23
24	.3360738	.5061915	.3492258	.5366313	.3625760	.5688145	24
25	.3362913	.5066852	.3494467	.5371530	.3628002	.5693664	25
26	.3365090	.5071793	.3496676	.5376752	.3630244	.5699188	26
27	.3367266	.5076739	.3498886	.5381980	.3632487	.5704717	27
28	.3369443	.5081690	.3501097	.5387212	.3634730	.5710252	28
29	.3371621	.5086645	.3503308	.5392449	.3636974	.5715792	29
30	0.3373800	0.5091605	0.3505520	0.5397690	0.3639218	0.5721337	30
31	.3375978	.5096569	.3507732	.5402937	.3641463	.5726887	31
32	.3378158	.5101538	.3509944	.5408189	.3643708	.5732443	32
33	.3380338	.5106511	.3512158	.5413445	.3645954	.5738004	33
34	.3382518	.5111489	.3514372	.5418706	.3648200	.5743570	34
35	.3384700	.5116472	.3516586	.5423973	.3650447	.5749141	35
36	.3386881	.5121459	.3518801	.5429244	.3652695	.5754718	36
37	.3389064	.5126450	.3521016	.5434520	.3654943	.5760300	37
38	.3391246	.5131446	.3523233	.5439801	.3657192	.5765887	38
39	.3393430	.5136447	.3525449	.5445087	.3659441	.5771479	39
40	0.3395614	0.5141452	0.3527666	0.5450378	0.3661690	0.5777077	40
41	.3397798	.5146462	.3529884	.5455673	.3663941	.5782680	41
42	.3399983	.5151477	.3532102	.5460974	.3666191	.5788289	42
43	.3402169	.5156496	.3534321	.5466280	.3668443	.5793902	43
44	.3404355	.5161520	.3536540	.5471590	.3670694	.5799521	44
45	.3406542	.5166548	.3538760	.5476906	.3672947	.5805146	45
46	.3408729	.5171581	.3540981	.5482226	.3675200	.5810776	46
47	.3410917	.5176619	.3543202	.5487552	.3677453	.5816411	47
48	.3413105	.5181661	.3545423	.5492882	.3679707	.5822051	48
49	.3415294	.5186708	.3547645	.5498218	.3681961	.5827697	49
50	0.3417484	0.5191759	0.3549868	0.5503558	0.3684216	0.5833348	50
51	.3419674	.5196815	.3552091	.5508904	.3686472	.5839005	51
52	.3421865	.5201876	.3554315	.5514254	.3688728	.5844667	52
53	.3424056	.5206942	.3556539	.5519610	.3690985	.5850334	53
54	.3426248	.5212012	.3558764	.5524970	.3693242	.5856007	54
55	.3428440	.5217087	.3560989	.5530335	.3695500	.5861685	55
56	.3430633	.5222166	.3563215	.5535706	.3697758	.5867369	56
57	.3432826	.5227250	.3565441	.5541081	.3700017	.5873058	57
58	.3435020	.5232339	.3567668	.5546462	.3702276	.5878752	58
59	.3437215	.5237433	.3569896	.5551848	.3704536	.5884452	59
60	0.3439410	0.5242531	0.3572124	0.5557238	0.3706796	0.5890157	60

51°			52°			53°		
Vers.	Ex. sec.		Vers.	Ex. sec.		Vers.	Ex. sec.	
0	0.3706796	0.5890157	0.3843385	0.6242692	0.3981850	0.6616401		0
1	.3709057	.5895868	.3845678	.6248743	.3984173	.6622819		1
2	.3711318	.5901584	.3847971	.6254799	.3986497	.6629243		2
3	.3713580	.5907306	.3850264	.6260861	.3988821	.6635673		3
4	.3715843	.5913033	.3852558	.6266929	.3991146	.6642110		4
5	.3718106	.5918766	.3854853	.6273003	.3993472	.6648553		5
6	.3720369	.5924504	.3857148	.6279083	.3995798	.6655002		6
7	.3722634	.5930247	.3859444	.6285169	.3998124	.6661458		7
8	.3724898	.5935996	.3861740	.6291261	.4000451	.6667920		8
9	.3727163	.5941751	.3864036	.6297359	.4002779	.6674389		9
10	0.3729429	0.5947511	0.3866334	0.6303462	0.4005107	0.6680864		10
11	.3731695	.5953276	.3868631	.6309572	.4007435	.6687345		11
12	.3733962	.5959048	.3870929	.6315688	.4009764	.6693833		12
13	.3736229	.5964824	.3873228	.6321809	.4012094	.6700328		13
14	.3738497	.5970606	.3875527	.6327937	.4014423	.6706828		14
15	.3740765	.5976394	.3877827	.6334070	.4016754	.6713336		15
16	.3743034	.5982187	.3880127	.6340210	.4019085	.6719850		16
17	.3745304	.5987986	.3882428	.6346355	.4021417	.6726370		17
18	.3747573	.5993790	.3884730	.6352507	.4023749	.6732897		18
19	.3749844	.5999600	.3887031	.6358664	.4026081	.6739430		19
20	0.3752115	0.6005416	0.3889334	0.6364828	0.4028414	0.6745970		20
21	.3754386	.6011237	.3891637	.6370997	.4030748	.6752517		21
22	.3756658	.6017064	.3893940	.6377173	.4033082	.6759070		22
23	.3758931	.6022896	.3896244	.6383355	.4035416	.6765629		23
24	.3761204	.6028734	.3898548	.6389542	.4037751	.6772195		24
25	.3763478	.6034577	.3900853	.6395736	.4040087	.6778768		25
26	.3765752	.6040426	.3903159	.6401936	.4042423	.6785347		26
27	.3768026	.6046281	.3905465	.6408142	.4044759	.6791933		27
28	.3770302	.6052142	.3907771	.6414354	.4047096	.6798525		28
29	.3772577	.6058008	.3910078	.6420572	.4049434	.6805124		29
30	0.3774854	0.6063879	0.3912386	0.6426796	0.4051772	0.6811730		30
31	.3777130	.6069757	.3914694	.6433027	.4054111	.6818342		31
32	.3779408	.6075640	.3917002	.6439263	.4056450	.6824961		32
33	.3781686	.6081528	.3919311	.6445506	.4058789	.6831586		33
34	.3783964	.6087423	.3921621	.6451754	.4061129	.6838219		34
35	.3786243	.6093323	.3923931	.6458009	.4063470	.6844857		35
36	.3788522	.6099228	.3926242	.6464270	.4065811	.6851503		36
37	.3790802	.6105140	.3928553	.6470537	.4068153	.6858155		37
38	.3793083	.6111057	.3930864	.6476811	.4070495	.6864814		38
39	.3795364	.6116980	.3933176	.6483090	.4072837	.6871479		39
40	0.3797645	0.6122908	0.3935489	0.6489376	0.4075181	0.6878151		40
41	.3799927	.6128843	.3937802	.6495668	.4077524	.6884830		41
42	.3802210	.6134783	.3940116	.6501966	.4079868	.6891516		42
43	.3804493	.6140728	.3942430	.6508270	.4082213	.6898208		43
44	.3806776	.6146680	.3944745	.6514581	.4084558	.6904907		44
45	.3809061	.6152637	.3947060	.6520898	.4086904	.6911613		45
46	.3811345	.6158600	.3949376	.6527221	.4089250	.6918326		46
47	.3813630	.6164569	.3951692	.6533550	.4091596	.6925045		47
48	.3815916	.6170544	.3954009	.6539885	.4093943	.6931771		48
49	.3818202	.6176524	.3956326	.6546227	.4096291	.6938504		49
50	0.3820489	0.6182510	0.3958644	0.6552575	0.4098639	0.6945244		50
51	.3822776	.6188502	.3960962	.6558929	.4100988	.6951990		51
52	.3825064	.6194500	.3963281	.6565290	.4103337	.6958744		52
53	.3827352	.6200504	.3965600	.6571657	.4105686	.6965504		53
54	.3829641	.6206513	.3967920	.6578030	.4108036	.6972271		54
55	.3831931	.6212528	.3970240	.6584409	.4110387	.6979044		55
56	.3834220	.6218549	.3972561	.6590795	.4112738	.6985825		56
57	.3836511	.6224576	.3974883	.6597187	.4115090	.6992612		57
58	.3838802	.6230609	.3977205	.6603586	.4117442	.6999407		58
59	.3841093	.6236648	.3979527	.6609990	.4119794	.7006208		59
60	0.3843385	0.6242692	0.3981850	0.6616401	0.4122147	0.7013016		60

54°			55°			56°		
	Vers.	Ex. sec.		Vers.	Ex. sec.		Vers.	Ex. sec.
0	0.4122147	0.7013016	0.4264236	0.7434468	0.4408071	0.7882916	0	
1	.4124501	.7019831	.4266619	.7441715	.4410483	.7890633	1	
2	.4126855	.7026653	.4269002	.7448969	.4412895	.7898357	2	
3	.4129210	.7033482	.4271386	.7456230	.4415308	.7906090	3	
4	.4131565	.7040318	.4273771	.7463499	.4417721	.7913831	4	
5	.4133920	.7047160	.4276156	.7470776	.4420135	.7921580	5	
6	.4136276	.7054010	.4278541	.7478060	.4422549	.7929337	6	
7	.4138633	.7060867	.4280927	.7485352	.4424964	.7937102	7	
8	.4140990	.7067730	.4283314	.7492651	.4427379	.7944876	8	
9	.4143348	.7074601	.4285701	.7499958	.4429794	.7952658	9	
10	0.4145706	0.7081478	0.4288088	0.7507273	0.4432210	0.7960449	10	
11	.4148064	.7088362	.4290476	.7514595	.4434627	.7968247	11	
12	.4150423	.7095254	.4292864	.7521924	.4437044	.7976054	12	
13	.4152783	.7102152	.4295253	.7529262	.4439461	.7983869	13	
14	.4155143	.7109058	.4297643	.7536607	.4441879	.7991693	14	
15	.4157503	.7115970	.4300032	.7543959	.4444298	.7999524	15	
16	.4159864	.7122890	.4302423	.7551320	.4446717	.8007365	16	
17	.4162226	.7129817	.4304813	.7558687	.4449136	.8015213	17	
18	.4164588	.7136750	.4307205	.7566063	.4451556	.8023070	18	
19	.4166950	.7143691	.4309597	.7573446	.4453976	.8030935	19	
20	0.4169313	0.7150639	0.4311989	0.7580837	0.4456397	0.8038809	20	
21	.4171677	.7157594	.4314381	.7588236	.4458818	.8046691	21	
22	.4174041	.7164556	.4316775	.7595642	.4461240	.8054582	22	
23	.4176405	.7171525	.4319168	.7603057	.4463662	.8062481	23	
24	.4178770	.7178501	.4321563	.7610478	.4466085	.8070388	24	
25	.4181136	.7185484	.4323957	.7617908	.4468508	.8078304	25	
26	.4183502	.7192475	.4326352	.7625345	.4470931	.8086228	26	
27	.4185868	.7199472	.4328748	.7632791	.4473355	.8094161	27	
28	.4188235	.7206477	.4331144	.7640244	.4475780	.8102102	28	
29	.4190603	.7213480	.4333541	.7647704	.4478205	.8110052	29	
30	0.4192970	0.7220508	0.4335938	0.7655173	0.4480630	0.8118010	30	
31	.4195339	.7227534	.4338335	.7662649	.4483056	.8125977	31	
32	.4197708	.7234568	.4340733	.7670133	.4485482	.8133953	32	
33	.4200077	.7241609	.4343132	.7677625	.4487909	.8141937	33	
34	.4202447	.7248657	.4345531	.7685125	.4490337	.8149929	34	
35	.4204817	.7255712	.4347930	.7692633	.4492764	.8157930	35	
36	.4207188	.7262774	.4350330	.7700149	.4495193	.8165940	36	
37	.4209560	.7269844	.4352730	.7707672	.4497621	.8173958	37	
38	.4211931	.7276921	.4355131	.7715204	.4500050	.8181985	38	
39	.4214304	.7284005	.4357533	.7722743	.4502480	.8190021	39	
40	0.4216677	0.7291096	0.4359934	0.7730290	0.4504910	0.8198065	40	
41	.4219050	.7298195	.4362337	.7737845	.4507341	.8206118	41	
42	.4221424	.7305301	.4364740	.7745400	.4509772	.8214179	42	
43	.4223798	.7312414	.4367143	.7752980	.4512203	.8222249	43	
44	.4226173	.7319535	.4369547	.7760559	.4514635	.8230328	44	
45	.4228548	.7326663	.4371951	.7768146	.4517068	.8238416	45	
46	.4230924	.7333798	.4374355	.7775741	.4519501	.8246512	46	
47	.4233300	.7340941	.4376761	.7783344	.4521934	.8254617	47	
48	.4235677	.7348091	.4379166	.7790955	.4524368	.8262731	48	
49	.4238054	.7355248	.4381572	.7798574	.4526802	.8270854	49	
50	0.4240432	0.7362413	0.4383979	0.7806201	0.4529237	0.8278985	50	
51	.4242810	.7369585	.4386386	.7813836	.4531672	.8287125	51	
52	.4245189	.7376764	.4388794	.7821479	.4534108	.8295274	52	
53	.4247568	.7383951	.4391202	.7829131	.4536544	.8303432	53	
54	.4249947	.7391145	.4393610	.7836790	.4538980	.8311599	54	
55	.4252328	.7398347	.4396019	.7844457	.4541417	.8319774	55	
56	.4254708	.7405556	.4398428	.7852133	.4543855	.8327959	56	
57	.4257089	.7412773	.4400838	.7859817	.4546293	.8336152	57	
58	.4259471	.7419997	.4403249	.7867508	.4548731	.8344354	58	
59	.4261853	.7427229	.4405660	.7875208	.4551170	.8352565	59	
60	0.4264236	0.7434468	0.4408071	0.7882916	0.4553610	0.8360785	60	

	57°		58°		59°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.4553610	0.8360785	0.4700807	0.8870799	0.4849619	0.9416040	0
1	.4556049	.8369013	.4703274	.8879589	.4852113	.9425445	1
2	.4558490	.8377251	.4705742	.8888388	.4854607	.9434861	2
3	.4560931	.8385498	.4708210	.8897197	.4857101	.9444288	3
4	.4563372	.8393753	.4710678	.8906016	.4859596	.9453725	4
5	.4565813	.8402018	.4713147	.8914845	.4862092	.9463173	5
6	.4568256	.8410292	.4715617	.8923684	.4864587	.9472632	6
7	.4570698	.8418574	.4718086	.8932532	.4867084	.9482102	7
8	.4573141	.8426866	.4720557	.8941391	.4869580	.9491583	8
9	.4575585	.8435166	.4723027	.8950259	.4872077	.9501075	9
10	0.4578029	0.8443476	0.4725498	0.8959138	0.4874575	0.9510577	10
11	.4580473	.8451795	.4727970	.8968026	.4877073	.9520091	11
12	.4582918	.8460123	.4730442	.8976924	.4879571	.9529615	12
13	.4585363	.8468460	.4732915	.8985832	.4882070	.9539150	13
14	.4587809	.8476806	.4735387	.8994750	.4884569	.9548697	14
15	.4590255	.8485161	.4737861	.9003678	.4887069	.9558254	15
16	.4592702	.8493525	.4740335	.9012616	.4889569	.9567822	16
17	.4595149	.8501898	.4742809	.9021564	.4892070	.9577402	17
18	.4597597	.8510281	.4745283	.9030522	.4894571	.9586992	18
19	.4600045	.8518672	.4747759	.9039491	.4897072	.9596593	19
20	0.4602493	0.8527073	0.4750234	0.9048469	0.4899574	0.9606206	20
21	.4604942	.8535483	.4752710	.9057457	.4902076	.9615829	21
22	.4607392	.8543903	.4755187	.9066456	.4904579	.9625464	22
23	.4609842	.8552331	.4757664	.9075464	.4907082	.9635110	23
24	.4612292	.8560769	.4760141	.9084483	.4909586	.9644767	24
25	.4614743	.8569216	.4762619	.9093512	.4912090	.9654435	25
26	.4617194	.8577672	.4765097	.9102551	.4914594	.9664114	26
27	.4619646	.8586138	.4767576	.9111600	.4917099	.9673805	27
28	.4622098	.8594612	.4770055	.9120659	.4919604	.9683507	28
29	.4624551	.8603097	.4772534	.9129729	.4922110	.9693220	29
30	0.4627004	0.8611590	0.4775014	0.9138809	0.4924616	0.9702944	30
31	.4629457	.8620093	.4777495	.9147899	.4927123	.9712680	31
32	.4631911	.8628605	.4779976	.9156999	.4929630	.9722427	32
33	.4634366	.8637126	.4782457	.9166110	.4932137	.9732185	33
34	.4636821	.8645657	.4784939	.9175230	.4934645	.9741954	34
35	.4639276	.8654197	.4787421	.9184362	.4937154	.9751735	35
36	.4641732	.8662747	.4789904	.9193503	.4939662	.9761527	36
37	.4644188	.8671306	.4792387	.9202655	.4942172	.9771331	37
38	.4646645	.8679875	.4794870	.9211817	.4944681	.9781146	38
39	.4649102	.8688453	.4797354	.9220990	.4947191	.9790972	39
40	0.4651560	0.8697040	0.4799839	0.9230173	0.4949702	0.9800810	40
41	.4654018	.8705637	.4802324	.9239366	.4952212	.9810659	41
42	.4656477	.8714244	.4804809	.9248570	.4954724	.9820520	42
43	.4658935	.8722859	.4807295	.9257784	.4957235	.9830393	43
44	.4661395	.8731485	.4809781	.9267009	.4959748	.9840276	44
45	.4663855	.8740120	.4812267	.9276244	.4962260	.9850172	45
46	.4666315	.8748764	.4814754	.9285490	.4964773	.9860080	46
47	.4668776	.8757419	.4817242	.9294740	.4967287	.9869997	47
48	.4671237	.8766082	.4819730	.9304013	.4969801	.9879927	48
49	.4673699	.8774755	.4822218	.9313290	.4972315	.9889869	49
50	0.4676161	0.8783438	0.4824707	0.9322578	0.4974830	0.9899822	50
51	.4678624	.8792131	.4827196	.9331876	.4977345	.9909787	51
52	.4681087	.8800833	.4829686	.9341185	.4979860	.9919764	52
53	.4683550	.8809545	.4832176	.9350505	.4982376	.9929752	53
54	.4686014	.8818266	.4834667	.9359835	.4984893	.9939753	54
55	.4688479	.8826998	.4837158	.9369176	.4987409	.9949764	55
56	.4690943	.8835738	.4839649	.9378527	.4989927	.9959788	56
57	.4693409	.8844489	.4842141	.9387889	.4992444	.9969823	57
58	.4695875	.8853249	.4844633	.9397262	.4994963	.9979870	58
59	.4698341	.8862019	.4847126	.9406646	.4997481	.9989929	59
60	0.4700807	0.8870799	0.4849619	0.9416040	0.5000000	1.0000000	60

	60°		61°		62°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.5000000	1.0000000	0.5151904	1.0626653	0.5305284	1.1300545	0
1	.5002519	1.0010083	.5154448	1.0637484	.5307853	1.1312205	1
2	.5005039	1.0020177	.5156993	1.0648328	.5310422	1.1323880	2
3	.5007559	1.0030283	.5159538	1.0659186	.5312991	1.1335570	3
4	.5010080	1.0040402	.5162084	1.0670056	.5315561	1.1347274	4
5	.5012601	1.0050532	.5164630	1.0680940	.5318131	1.1358993	5
6	.5015123	1.0060674	.5167176	1.0691836	.5320702	1.1370726	6
7	.5017645	1.0070828	.5169723	1.0702746	.5323273	1.1382475	7
8	.5020167	1.0080994	.5172270	1.0713670	.5325844	1.1394238	8
9	.5022690	1.0091172	.5174818	1.0724606	.5328416	1.1406015	9
10	0.5025213	1.0101362	0.5177366	1.0735556	0.5330988	1.1417808	10
11	.5027736	1.0111564	.5179914	1.0746519	.5333561	1.1429615	11
12	.5030260	1.0121779	.5182463	1.0757496	.5336134	1.1441438	12
13	.5032785	1.0132005	.5185013	1.0768486	.5338707	1.1453275	13
14	.5035310	1.0142243	.5187562	1.0779489	.5341281	1.1465127	14
15	.5037835	1.0152494	.5190112	1.0790506	.5343855	1.1476993	15
16	.5040361	1.0162756	.5192663	1.0801536	.5346429	1.1488875	16
17	.5042887	1.0173031	.5195214	1.0812580	.5349004	1.1500772	17
18	.5045413	1.0183318	.5197765	1.0823637	.5351580	1.1512684	18
19	.5047940	1.0193618	.5200317	1.0834708	.5354155	1.1524611	19
20	0.5050468	1.0203929	0.5202869	1.0845792	0.5356731	1.1536553	20
21	.5052995	1.0214253	.5205421	1.0856890	.5359308	1.1548510	21
22	.5055524	1.0224589	.5207974	1.0868002	.5361885	1.1560482	22
23	.5058052	1.0234937	.5210528	1.0879127	.5364462	1.1572469	23
24	.5060581	1.0245297	.5213081	1.0890265	.5367040	1.1584471	24
25	.5063111	1.0255670	.5215636	1.0901418	.5369618	1.1596489	25
26	.5065641	1.0266056	.5218190	1.0912584	.5372196	1.1608522	26
27	.5068171	1.0276453	.5220745	1.0923764	.5374775	1.1620570	27
28	.5070702	1.0286863	.5223300	1.0934957	.5377354	1.1632633	28
29	.5073233	1.0297286	.5225856	1.0946164	.5379934	1.1644712	29
30	0.5075764	1.0307720	0.5228412	1.0957385	0.5382514	1.1656806	30
31	.5078296	1.0318168	.5230969	1.0968620	.5385094	1.1668915	31
32	.5080829	1.0328628	.5233526	1.0979869	.5387675	1.1681040	32
33	.5083362	1.0339100	.5236083	1.0991131	.5390256	1.1693180	33
34	.5085895	1.0349585	.5238641	1.1002408	.5392838	1.1705335	34
35	.5088428	1.0360082	.5241199	1.1013698	.5395420	1.1717506	35
36	.5090962	1.0370592	.5243758	1.1025002	.5398002	1.1729693	36
37	.5093497	1.0381114	.5246317	1.1036320	.5400585	1.1741895	37
38	.5096032	1.0391649	.5248876	1.1047652	.5403168	1.1754113	38
39	.5098567	1.0402197	.5251436	1.1058998	.5405752	1.1766346	39
40	0.5101103	1.0412757	0.5253996	1.1070359	0.5408335	1.1778595	40
41	.5103639	1.0423330	.5256557	1.1081733	.5410920	1.1790859	41
42	.5106175	1.0433916	.5259118	1.1093121	.5413504	1.1803139	42
43	.5108712	1.0444515	.5261679	1.1104523	.5416090	1.1815435	43
44	.5111250	1.0455126	.5264241	1.1115940	.5418675	1.1827746	44
45	.5113788	1.0465750	.5266803	1.1127371	.5421261	1.1840074	45
46	.5116326	1.0476386	.5269366	1.1138815	.5423847	1.1852417	46
47	.5118864	1.0487036	.5271929	1.1150274	.5426434	1.1864775	47
48	.5121403	1.0497698	.5274492	1.1161748	.5429021	1.1877150	48
49	.5123943	1.0508373	.5277056	1.1173235	.5431608	1.1889541	49
50	0.5126483	1.0519061	0.5279620	1.1184737	0.5434196	1.1901947	50
51	.5129023	1.0529762	.5282185	1.1196253	.5436784	1.1914370	51
52	.5131564	1.0540476	.5284750	1.1207783	.5439373	1.1926808	52
53	.5134105	1.0551203	.5287315	1.1219328	.5441962	1.1939262	53
54	.5136646	1.0561942	.5289881	1.1230887	.5444551	1.1951733	54
55	.5139188	1.0572695	.5292447	1.1242460	.5447141	1.1964219	55
56	.5141730	1.0583460	.5295014	1.1254048	.5449731	1.1976721	56
57	.5144273	1.0594239	.5297581	1.1265651	.5452321	1.1989240	57
58	.5146816	1.0605031	.5300148	1.1277267	.5454912	1.2001775	58
59	.5149360	1.0615836	.5302716	1.1288899	.5457503	1.2014326	59
60	0.5151904	1.0626653	0.5305284	1.1300545	0.5460095	1.2026893	60

	63°		64°		65°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.5460095	1.2026893	0.5616289	1.2811720	0.5773817	1.3662016	0
1	.5462687	1.2039476	.5618903	1.2825335	.5776454	1.3676787	1
2	.5465279	1.2052075	.5621518	1.2838967	.5779091	1.3691578	2
3	.5467872	1.2064691	.5624134	1.2852618	.5781728	1.3706390	3
4	.5470465	1.2077323	.5626749	1.2866286	.5784366	1.3721222	4
5	.5473059	1.2089972	.5629366	1.2879974	.5787004	1.3736075	5
6	.5475653	1.2102637	.5631982	1.2893679	.5789642	1.3750949	6
7	.5478247	1.2115318	.5634599	1.2907403	.5792281	1.3765843	7
8	.5480842	1.2128016	.5637216	1.2921145	.5794920	1.3780758	8
9	.5483437	1.2140730	.5639834	1.2934906	.5797559	1.3795694	9
10	0.5486033	1.2153460	0.5642452	1.2948685	0.5800199	1.3810650	10
11	.5488628	1.2166208	.5645070	1.2962483	.5802839	1.3825627	11
12	.5491225	1.2178971	.5647689	1.2976299	.5805479	1.3840625	12
13	.5493821	1.2191752	.5650308	1.2990134	.5808120	1.3855645	13
14	.5496418	1.2204548	.5652928	1.3003988	.5810761	1.3870685	14
15	.5499016	1.2217362	.5655547	1.3017860	.5813403	1.3885746	15
16	.5501613	1.2230192	.5658168	1.3031751	.5816044	1.3900828	16
17	.5504211	1.2243039	.5660788	1.3045660	.5818687	1.3915931	17
18	.5506810	1.2255903	.5663409	1.3059588	.5821329	1.3931055	18
19	.5509409	1.2268783	.5666030	1.3073536	.5823972	1.3946201	19
20	0.5512008	1.2281681	0.5668652	1.3087501	0.5826615	1.3961367	20
21	.5514608	1.2294595	.5671274	1.3101486	.5829259	1.3976555	21
22	.5517208	1.2307526	.5673897	1.3115490	.5831903	1.3991764	22
23	.5519808	1.2320474	.5676519	1.3129513	.5834547	1.4006995	23
24	.5522409	1.2333438	.5679143	1.3143554	.5837192	1.4022247	24
25	.5525010	1.2346420	.5681766	1.3157615	.5839837	1.4037520	25
26	.5527612	1.2359419	.5684390	1.3171695	.5842483	1.4052815	26
27	.5530214	1.2372435	.5687014	1.3185794	.5845128	1.4068132	27
28	.5532816	1.2385468	.5689639	1.3199912	.5847774	1.4083469	28
29	.5535419	1.2398517	.5692264	1.3214049	.5850421	1.4098829	29
30	0.5538022	1.2411585	0.5694889	1.3228205	0.5853068	1.4114210	30
31	.5540625	1.2424669	.5697515	1.3242381	.5855715	1.4129613	31
32	.5543229	1.2437770	.5700141	1.3256575	.5858362	1.4145038	32
33	.5545833	1.2450889	.5702767	1.3270790	.5861010	1.4160484	33
34	.5548438	1.2464025	.5705394	1.3285023	.5863658	1.4175952	34
35	.5551043	1.2477178	.5708021	1.3299276	.5866307	1.4191442	35
36	.5553648	1.2490348	.5710649	1.3313548	.5868956	1.4206954	36
37	.5556254	1.2503536	.5713277	1.3327840	.5871605	1.4222488	37
38	.5558860	1.2516741	.5715905	1.3342152	.5874255	1.4238044	38
39	.5561466	1.2529964	.5718533	1.3356482	.5876904	1.4253622	39
40	0.5564073	1.2543204	0.5721162	1.3370833	0.5879555	1.4269222	40
41	.5566681	1.2556461	.5723792	1.3385203	.5882205	1.4284844	41
42	.5569288	1.2569736	.5726421	1.3399593	.5884856	1.4300489	42
43	.5571896	1.2583029	.5729051	1.3414002	.5887508	1.4316155	43
44	.5574504	1.2596339	.5731682	1.3428432	.5890159	1.4331844	44
45	.5577113	1.2609667	.5734313	1.3442881	.5892811	1.4347555	45
46	.5579722	1.2623012	.5736944	1.3457349	.5895464	1.4363289	46
47	.5582332	1.2636376	.5739575	1.3471838	.5898117	1.4379045	47
48	.5584941	1.2649756	.5742207	1.3486347	.5900770	1.4394823	48
49	.5587552	1.2663155	.5744839	1.3500875	.5903423	1.4410624	49
50	0.5590162	1.2676571	0.5747472	1.3515424	0.5906077	1.4426448	50
51	.5592773	1.2690005	.5750105	1.3529992	.5908731	1.4442294	51
52	.5595385	1.2703457	.5752738	1.3544581	.5911385	1.4458163	52
53	.5597996	1.2716927	.5755372	1.3559189	.5914040	1.4474054	53
54	.5600608	1.2730415	.5758006	1.3573818	.5916695	1.4489968	54
55	.5603221	1.2743921	.5760640	1.3588467	.5919351	1.4505905	55
56	.5605834	1.2757445	.5763275	1.3603136	.5922007	1.4521865	56
57	.5608447	1.2770987	.5765910	1.3617826	.5924663	1.4537848	57
58	.5611060	1.2784546	.5768545	1.3632535	.5927319	1.4553853	58
59	.5613674	1.2798124	.5771181	1.3647265	.5929976	1.4569882	59
60	0.5616289	1.2811720	0.5773817	1.3662016	0.5932634	1.4585933	60

	66°		67°		68°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.5932634	1.4585933	0.6092689	1.5593047	0.6253934	1.6694672	0
1	.5935291	1.4602008	.6095367	1.5610599	.6256631	1.6713906	1
2	.5937949	1.4618106	.6098045	1.5628176	.6259329	1.6733171	2
3	.5940607	1.4634227	.6100723	1.5645781	.6262027	1.6752465	3
4	.5943266	1.4650371	.6103402	1.5663412	.6264725	1.6771790	4
5	.5945925	1.4666538	.6106081	1.5681069	.6267423	1.6791145	5
6	.5948584	1.4682729	.6108760	1.5698752	.6270122	1.6810530	6
7	.5951244	1.4698943	.6111440	1.5716462	.6272821	1.6829945	7
8	.5953904	1.4715181	.6114120	1.5734199	.6275521	1.6849391	8
9	.5956564	1.4731442	.6116801	1.5751963	.6278220	1.6868867	9
10	0.5959225	1.4747726	0.6119482	1.5769753	0.6280921	1.6888374	10
11	.5961886	1.4764034	.6122163	1.5787570	.6283621	1.6907912	11
12	.5964547	1.4780366	.6124844	1.5805414	.6286332	1.6927480	12
13	.5967209	1.4796721	.6127526	1.5823284	.6289023	1.6947079	13
14	.5969871	1.4813100	.6130208	1.5841182	.6291724	1.6966709	14
15	.5972533	1.4829503	.6132890	1.5859107	.6294426	1.6986370	15
16	.5975196	1.4845929	.6135573	1.5877058	.6297128	1.7006061	16
17	.5977859	1.4862380	.6138256	1.5895037	.6299830	1.7025784	17
18	.5980522	1.4878854	.6140940	1.5913043	.6302532	1.7045538	18
19	.5983186	1.4895352	.6143623	1.5931077	.6305235	1.7065323	19
20	0.5985850	1.4911874	0.6146307	1.5949137	0.6307939	1.7085139	20
21	.5988514	1.4928421	.6148992	1.5967225	.6310642	1.7104987	21
22	.5991179	1.4944991	.6151676	1.5985341	.6313346	1.7124866	22
23	.5993844	1.4961586	.6154361	1.6003484	.6316050	1.7144777	23
24	.5996510	1.4978204	.6157047	1.6021654	.6318754	1.7164719	24
25	.5999175	1.4994848	.6159732	1.6039852	.6321450	1.7184693	25
26	.6001842	1.5011515	.6162418	1.6058078	.6324164	1.7204698	26
27	.6004508	1.5028207	.6165105	1.6076332	.6326870	1.7224735	27
28	.6007175	1.5044923	.6167791	1.6094613	.6329575	1.7244804	28
29	.6009842	1.5061663	.6170478	1.6112922	.6332281	1.7264905	29
30	0.6012509	1.5078428	0.6173166	1.6131259	0.6334988	1.7285038	30
31	.6015177	1.5095218	.6175853	1.6149624	.6337694	1.7305203	31
32	.6017845	1.5112032	.6178541	1.6168018	.6340401	1.7325400	32
33	.6020514	1.5128871	.6181230	1.6186439	.6343109	1.7345630	33
34	.6023182	1.5145735	.6183918	1.6204888	.6345816	1.7365892	34
35	.6025852	1.5162624	.6186607	1.6223366	.6348524	1.7386186	35
36	.6028521	1.5179537	.6189296	1.6241872	.6351232	1.7406512	36
37	.6031191	1.5196475	.6191986	1.6260406	.6353941	1.7426871	37
38	.6033861	1.5213438	.6194676	1.6278969	.6356649	1.7447263	38
39	.6036532	1.5230426	.6197366	1.6297560	.6359359	1.7467687	39
40	0.6039202	1.5247440	0.6200056	1.6316180	0.6362068	1.7488144	40
41	.6041873	1.5264478	.6202747	1.6334828	.6364778	1.7508634	41
42	.6044545	1.5281541	.6205438	1.6353506	.6367488	1.7529157	42
43	.6047217	1.5298630	.6208130	1.6372211	.6370198	1.7549712	43
44	.6049889	1.5315744	.6210822	1.6390946	.6372909	1.7570301	44
45	.6052561	1.5332883	.6213514	1.6409710	.6375620	1.7590923	45
46	.6055234	1.5350048	.6216206	1.6428502	.6378331	1.7611578	46
47	.6057907	1.5367238	.6218899	1.6447323	.6381042	1.7632267	47
48	.6060581	1.5384453	.6221592	1.6466174	.6383754	1.7652988	48
49	.6063255	1.5401694	.6224286	1.6485054	.6386466	1.7673744	49
50	0.6065929	1.5418961	0.6226979	1.6503962	0.6389179	1.7694532	50
51	.6068603	1.5436253	.6229673	1.6522901	.6391892	1.7715355	51
52	.6071278	1.5453571	.6232368	1.6541868	.6394605	1.7736211	52
53	.6073953	1.5470915	.6235062	1.6560865	.6397318	1.7757100	53
54	.6076629	1.5488284	.6237757	1.6579891	.6400032	1.7778024	54
55	.6079305	1.5505680	.6240453	1.6598947	.6402746	1.7798982	55
56	.6081981	1.5523101	.6243148	1.6618033	.6405460	1.7819973	56
57	.6084657	1.5540548	.6245844	1.6637148	.6408175	1.7840999	57
58	.6087334	1.5558022	.6248541	1.6656292	.6410890	1.7862059	58
59	.6090011	1.5575521	.6251237	1.6675467	.6413605	1.7883153	59
60	0.6092689	1.5593047	0.6253934	1.6694672	0.6416321	1.7904281	60

	69°		70°		71°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.6416321	1.7904281	0.6579799	1.9238044	0.6744318	2.0715535	0
1	.6419036	1.7925444	.6582532	1.9261431	.6747069	2.0741507	1
2	.6421752	1.7946641	.6585266	1.9284858	.6749820	2.0767525	2
3	.6424469	1.7967873	.6588000	1.9308326	.6752571	2.0793590	3
4	.6427186	1.7989140	.6590735	1.9331833	.6755322	2.0819702	4
5	.6429903	1.8010441	.6593469	1.9355380	.6758074	2.0845860	5
6	.6432620	1.8031777	.6596204	1.9378968	.6760826	2.0872066	6
7	.6435338	1.8053148	.6598940	1.9402597	.6763578	2.0898319	7
8	.6438056	1.8074554	.6601675	1.9426265	.6766330	2.0924620	8
9	.6440774	1.8095995	.6604411	1.9449975	.6769083	2.0950967	9
10	0.6443492	1.8117471	0.6607148	1.9473725	0.6771836	2.0977363	10
11	.6446211	1.8138982	.6609884	1.9497516	.6774589	2.1003805	11
12	.6448930	1.8160529	.6612621	1.9521348	.6777343	2.1030296	12
13	.6451650	1.8182111	.6615358	1.9545221	.6780097	2.1056835	13
14	.6454370	1.8203729	.6618095	1.9569135	.6782851	2.1083422	14
15	.6457090	1.8225382	.6620833	1.9593090	.6785605	2.1110057	15
16	.6459810	1.8247071	.6623571	1.9617087	.6788360	2.1136740	16
17	.6462531	1.8268796	.6626309	1.9641125	.6791115	2.1163472	17
18	.6465252	1.8290556	.6629047	1.9665205	.6793870	2.1190252	18
19	.6467973	1.8312353	.6631786	1.9689327	.6796626	2.1217081	19
20	0.6470694	1.8334185	0.6634525	1.9713490	0.6799381	2.1243959	20
21	.6473416	1.8356054	.6637265	1.9737695	.6802137	2.1270886	21
22	.6476138	1.8377958	.6640004	1.9761942	.6804894	2.1297862	22
23	.6478861	1.8399899	.6642744	1.9786231	.6807650	2.1324887	23
24	.6481584	1.8421877	.6645484	1.9810563	.6810407	2.1351962	24
25	.6484307	1.8443891	.6648225	1.9834936	.6813164	2.1379086	25
26	.6487030	1.8465941	.6650966	1.9859352	.6815921	2.1406259	26
27	.6489753	1.8488028	.6653707	1.9883811	.6818679	2.1433483	27
28	.6492477	1.8510152	.6656448	1.9908312	.6821437	2.1460756	28
29	.6495202	1.8532312	.6659190	1.9932856	.6824195	2.1488079	29
30	0.6497926	1.8554510	0.6661931	1.9957443	0.6826953	2.1515453	30
31	.6500651	1.8576744	.6664674	1.9982073	.6829712	2.1542877	31
32	.6503376	1.8599015	.6667416	2.0006746	.6832471	2.1570351	32
33	.6506102	1.8621324	.6670159	2.0031462	.6835230	2.1597876	33
34	.6508827	1.8643670	.6672902	2.0056221	.6837990	2.1625452	34
35	.6511553	1.8666053	.6675645	2.0081024	.6840750	2.1653078	35
36	.6514280	1.8688474	.6678389	2.0105870	.6843510	2.1680756	36
37	.6517006	1.8710932	.6681133	2.0130760	.6846270	2.1708484	37
38	.6519733	1.8733428	.6683877	2.0155694	.6849031	2.1736264	38
39	.6522460	1.8755961	.6686621	2.0180672	.6851791	2.1764095	39
40	0.6525188	1.8778532	0.6689366	2.0205693	0.6854552	2.1791978	40
41	.6527915	1.8801142	.6692111	2.0230759	.6857314	2.1819913	41
42	.6530643	1.8823789	.6694856	2.0255868	.6860075	2.1847899	42
43	.6533372	1.8846474	.6697602	2.0281023	.6862837	2.1875937	43
44	.6536100	1.8869198	.6700347	2.0306221	.6865600	2.1904028	44
45	.6538829	1.8891960	.6703094	2.0331464	.6868362	2.1932170	45
46	.6541559	1.8914760	.6705840	2.0356752	.6871125	2.1960365	46
47	.6544288	1.8937598	.6708587	2.0382084	.6873888	2.1988613	47
48	.6547018	1.8960475	.6711334	2.0407462	.6876651	2.2016913	48
49	.6549748	1.8983391	.6714081	2.0432884	.6879414	2.2045266	49
50	0.6552479	1.9006346	0.6716828	2.0458352	0.6882178	2.2073673	50
51	.6555209	1.9029339	.6719576	2.0483864	.6884942	2.2102132	51
52	.6557940	1.9052372	.6722324	2.0509423	.6887706	2.2130644	52
53	.6560671	1.9075443	.6725072	2.0535026	.6890471	2.2159210	53
54	.6563403	1.9098553	.6727821	2.0560675	.6893236	2.2187830	54
55	.6566135	1.9121703	.6730570	2.0586370	.6896001	2.2216503	55
56	.6568867	1.9144892	.6733319	2.0612111	.6898766	2.2245230	56
57	.6571600	1.9168121	.6736068	2.0637898	.6901532	2.2274011	57
58	.6574332	1.9191389	.6738818	2.0663731	.6904298	2.2302846	58
59	.6577065	1.9214697	.6741568	2.0689610	.6907064	2.2331736	59
60	0.6579799	1.9238044	0.6744318	2.0715535	0.6909830	2.2360680	60

72°			73°			74°		
	Vers.	Ex. sec.		Vers.	Ex. sec.		Vers.	Ex. sec.
0	0.6909830	2.2360680	0.7076283	2.4203036	0.7243626	2.6279553	0	
1	.6912597	2.2389678	.7079065	2.4235611	.7246423	2.6316395	1	
2	.6915364	2.2418732	.7081847	2.4268251	.7249219	2.6353316	2	
3	.6918131	2.2447840	.7084629	2.4300956	.7252016	2.6390315	3	
4	.6920898	2.2477003	.7087412	2.4333727	.7254813	2.6427392	4	
5	.6923666	2.2506222	.7090195	2.4366563	.7257610	2.6464548	5	
6	.6926434	2.2535496	.7092978	2.4399465	.7260408	2.6501783	6	
7	.6929202	2.2564825	.7095761	2.4432433	.7263206	2.6539097	7	
8	.6931970	2.2594211	.7098545	2.4465467	.7266003	2.6576491	8	
9	.6934739	2.2623652	.7101329	2.4498568	.7268802	2.6613964	9	
10	0.6937508	2.2653149	0.7104113	2.4531735	0.7271600	2.6651518	10	
11	.6940277	2.2682702	.7106897	2.4564969	.7274399	2.6689151	11	
12	.6943047	2.2712311	.7109682	2.4598269	.7277198	2.6726865	12	
13	.6945817	2.2741977	.7112467	2.4631637	.7279997	2.6764660	13	
14	.6948587	2.2771700	.7115252	2.4665073	.7282796	2.6802536	14	
15	.6951357	2.2801479	.7118037	2.4698576	.7285596	2.6840493	15	
16	.6954128	2.2831316	.7120823	2.4732146	.7288395	2.6878532	16	
17	.6956898	2.2861209	.7123609	2.4765785	.7291195	2.6916652	17	
18	.6959669	2.2891160	.7126395	2.4799492	.7293996	2.6954854	18	
19	.6962441	2.2921168	.7129181	2.4833267	.7296796	2.6993139	19	
20	0.6965212	2.2951234	0.7131968	2.4867110	0.7299597	2.7031506	20	
21	.6967984	2.2981357	.7134754	2.4901023	.7302398	2.7069956	21	
22	.6970756	2.3011539	.7137542	2.4935004	.7305199	2.7108489	22	
23	.6973529	2.3041778	.7140329	2.4969055	.7308000	2.7147105	23	
24	.6976301	2.3072076	.7143116	2.5003175	.7310802	2.7185805	24	
25	.6979074	2.3102432	.7145904	2.5037365	.7313604	2.7224589	25	
26	.6981847	2.3132847	.7148692	2.5071625	.7316406	2.7263457	26	
27	.6984620	2.3163320	.7151480	2.5105954	.7319208	2.7302409	27	
28	.6987394	2.3193853	.7154269	2.5140354	.7322011	2.7341446	28	
29	.6990168	2.3224444	.7157058	2.5174824	.7324813	2.7380568	29	
30	0.6992942	2.3255095	0.7159847	2.5209365	0.7327616	2.7419775	30	
31	.6995716	2.3285805	.7162636	2.5243977	.7330419	2.7459068	31	
32	.6998491	2.3316575	.7165425	2.5278660	.7333223	2.7498447	32	
33	.7001266	2.3347405	.7168215	2.5313414	.7336027	2.7537911	33	
34	.7004041	2.3378294	.7171005	2.5348240	.7338830	2.7577462	34	
35	.7006816	2.3409241	.7173795	2.5383138	.7341634	2.7617100	35	
36	.7009592	2.3440251	.7176585	2.5418107	.7344439	2.7656824	36	
37	.7012368	2.3471324	.7179376	2.5453149	.7347243	2.7696636	37	
38	.7015144	2.3502455	.7182167	2.5488263	.7350048	2.7736535	38	
39	.7017921	2.3533647	.7184958	2.5523450	.7352853	2.7776522	39	
40	0.7020697	2.3564900	0.7187749	2.5558710	0.7355658	2.7816596	40	
41	.7023474	2.3596214	.7190541	2.5594042	.7358464	2.7856760	41	
42	.7026251	2.3627589	.7193333	2.5629448	.7361270	2.7897011	42	
43	.7029029	2.3659023	.7196125	2.5664928	.7364075	2.7937352	43	
44	.7031806	2.3690524	.7198917	2.5700481	.7366882	2.7977782	44	
45	.7034584	2.3722084	.7201710	2.5736108	.7369688	2.8018301	45	
46	.7037362	2.3753707	.7204503	2.5771810	.7372494	2.8058911	46	
47	.7040141	2.3785391	.7207296	2.5807586	.7375301	2.8099610	47	
48	.7042919	2.3817138	.7210089	2.5843437	.7378108	2.8140399	48	
49	.7045698	2.3848948	.7212882	2.5879362	.7380915	2.8181280	49	
50	0.7048478	2.3880820	0.7215676	2.5915363	0.7383723	2.8222251	50	
51	.7051257	2.3912755	.7218470	2.5951439	.7386531	2.8263313	51	
52	.7054037	2.3944754	.7221264	2.5987590	.7389338	2.8304467	52	
53	.7056817	2.3976816	.7224059	2.6023818	.7392147	2.8345713	53	
54	.7059597	2.4008941	.7226853	2.6060121	.7394955	2.8387052	54	
55	.7062377	2.4041130	.7229648	2.6096501	.7397763	2.8428482	55	
56	.7065158	2.4073382	.7232444	2.6132957	.7400572	2.8470006	56	
57	.7067939	2.4105699	.7235239	2.6169490	.7403381	2.8511622	57	
58	.7070720	2.4138080	.7238035	2.6206101	.7406190	2.8553332	58	
59	.7073501	2.4170526	.7240830	2.6242788	.7409000	2.8595135	59	
60	0.7076283	2.4203036	0.7243626	2.6279553	0.7411810	2.8637033	60	

	75°		76°		77°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.7411810	2.8637033	0.7580781	3.1335655	0.7750489	3.4454115	0
1	.7414619	2.8679025	.7583604	3.1383939	.7753324	3.4510198	1
2	.7417430	2.8721112	.7586426	3.1432339	.7756158	3.4566428	2
3	.7420240	2.8763293	.7589249	3.1480856	.7758993	3.4622803	3
4	.7423050	2.8805570	.7592073	3.1529491	.7761828	3.4679324	4
5	.7425861	2.8847943	.7594896	3.1578243	.7764663	3.4735993	5
6	.7428672	2.8890411	.7597720	3.1627114	.7767499	3.4792810	6
7	.7431483	2.8932976	.7600543	3.1676102	.7770334	3.4849775	7
8	.7434295	2.8975637	.7603367	3.1725210	.7773170	3.4906889	8
9	.7437106	2.9018395	.7606192	3.1774438	.7776006	3.4964152	9
10	0.7439918	2.9061250	0.7609016	3.1823785	0.7778842	3.5021565	10
11	.7442730	2.9104203	.7611841	3.1873258	.7781679	3.5079129	11
12	.7445542	2.9147254	.7614665	3.1922840	.7784515	3.5136844	12
13	.7448355	2.9190403	.7617490	3.1972549	.7787352	3.5194711	13
14	.7451168	2.9233651	.7620316	3.2022380	.7790189	3.5252730	14
15	.7453981	2.9276997	.7623141	3.2072333	.7793026	3.5310903	15
16	.7456794	2.9320443	.7625967	3.2122408	.7795863	3.5369229	16
17	.7459607	2.9363988	.7628793	3.2172606	.7798700	3.5427709	17
18	.7462421	2.9407633	.7631619	3.2222928	.7801538	3.5486344	18
19	.7465234	2.9451379	.7634445	3.2273373	.7804376	3.5545134	19
20	0.7468048	2.9495224	0.7637271	3.2323943	0.7807214	3.5604080	20
21	.7470863	2.9539171	.7640098	3.2374637	.7810052	3.5663183	21
22	.7473677	2.9583219	.7642925	3.2425457	.7812890	3.5722444	22
23	.7476492	2.9627369	.7645752	3.2476402	.7815729	3.5781862	23
24	.7479306	2.9671621	.7648579	3.2527474	.7818568	3.5841439	24
25	.7482121	2.9715975	.7651406	3.2578671	.7821407	3.5901174	25
26	.7484937	2.9760431	.7654234	3.2629996	.7824246	3.5961070	26
27	.7487752	2.9804991	.7657062	3.2681449	.7827085	3.6021126	27
28	.7490568	2.9849654	.7659890	3.2733029	.7829924	3.6081343	28
29	.7493384	2.9894421	.7662718	3.2784738	.7832764	3.6141722	29
30	0.7496200	2.9939292	0.7665546	3.2836576	0.7835604	3.6202263	30
31	.7499016	2.9984267	.7668375	3.2888543	.7838444	3.6262967	31
32	.7501833	3.0029347	.7671204	3.2940640	.7841284	3.6323835	32
33	.7504650	3.0074532	.7674033	3.2992867	.7844124	3.6384867	33
34	.7507467	3.0119823	.7676862	3.3045225	.7846965	3.6446064	34
35	.7510284	3.0165219	.7679691	3.3097715	.7849806	3.6507427	35
36	.7513101	3.0210722	.7682521	3.3150336	.7852647	3.6568956	36
37	.7515919	3.0256332	.7685351	3.3203090	.7855488	3.6630652	37
38	.7518737	3.0302048	.7688181	3.3255977	.7858329	3.6692516	38
39	.7521555	3.0347872	.7691011	3.3308996	.7861171	3.6754548	39
40	0.7524373	3.0393804	0.7693841	3.3362150	0.7864012	3.6816748	40
41	.7527191	3.0439844	.7696672	3.3415438	.7866854	3.6879119	41
42	.7530010	3.0485992	.7699503	3.3468861	.7869696	3.6941660	42
43	.7532829	3.0532249	.7702334	3.3522419	.7872538	3.7004372	43
44	.7535648	3.0578615	.7705165	3.3576113	.7875381	3.7067256	44
45	.7538467	3.0625091	.7707996	3.3629943	.7878223	3.7130313	45
46	.7541287	3.0671677	.7710828	3.3683910	.7881066	3.7193542	46
47	.7544106	3.0718374	.7713659	3.3738015	.7883909	3.7256945	47
48	.7546926	3.0765181	.7716491	3.3792257	.7886752	3.7320524	48
49	.7549746	3.0812100	.7719323	3.3846638	.7889595	3.7384277	49
50	0.7552567	3.0859130	0.7722156	2.3901158	0.7892439	3.7448206	50
51	.7555387	3.0906272	.7724988	3.3955817	.7895282	3.7512312	51
52	.7558208	3.0953526	.7727821	3.4010616	.7898126	3.7576596	52
53	.7561029	3.1000893	.7730654	3.4065556	.7900970	3.7641058	53
54	.7563850	3.1048374	.7733487	3.4120637	.7903814	3.7705699	54
55	.7566671	3.1095967	.7736320	3.4175859	.7906659	3.7770519	55
56	.7569493	3.1143675	.7739154	3.4231224	.7909503	3.7835520	56
57	.7572315	3.1191498	.7741987	3.4286731	.7912348	3.7900702	57
58	.7575137	3.1239435	.7744821	3.4342382	.7915193	3.7966066	58
59	.7577959	3.1287487	.7747655	3.4398176	.7918038	3.8031613	59
60	0.7580781	3.1335655	0.7750489	3.4454115	0.7920883	3.8097343	60

	78°		79°		80°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.7920883	3.8097343	0.8091910	4.2408431	0.8263518	4.7587705	0
1	.7923728	3.8163258	.8094766	4.2486979	.8266383	4.7682867	1
2	.7926574	3.8229557	.8097621	4.2565768	.8269248	4.7778350	2
3	.7929420	3.8295643	.8100477	4.2644798	.8272113	4.7874153	3
4	.7932266	3.8362114	.8103333	4.2724070	.8274978	4.7970280	4
5	.7935112	3.8428774	.8106189	4.2803587	.8277844	4.8066732	5
6	.7937958	3.8495621	.8109046	4.2883347	.8280709	4.8163510	6
7	.7940805	3.8562657	.8111902	4.2963354	.8283575	4.8260617	7
8	.7943651	3.8629883	.8114759	4.3043608	.8286440	4.8358053	8
9	.7946498	3.8697299	.8117615	4.3124109	.8289306	4.8455820	9
10	0.7949345	3.8764907	0.8120472	4.3204860	0.8292172	4.8553921	10
11	.7952192	3.8832707	.8123330	4.3285861	.8295039	4.8652356	11
12	.7955039	3.8900700	.8126187	4.3367114	.8297905	4.8751128	12
13	.7957887	3.8968886	.8129044	4.3448620	.8300772	4.8850238	13
14	.7960735	3.9037267	.8131902	4.3530379	.8303638	4.8949688	14
15	.7963582	3.9105844	.8134760	4.3612393	.8306505	4.9049479	15
16	.7966431	3.9174616	.8137618	4.3694664	.8309372	4.9149614	16
17	.7969279	3.9243586	.8140476	4.3777192	.8312239	4.9250095	17
18	.7972127	3.9312754	.8143334	4.3859979	.8315106	4.9350922	18
19	.7974976	3.9382120	.8146192	4.3943026	.8317974	4.9452098	19
20	0.7977824	3.9451687	0.8149051	4.4026333	0.8320841	4.9553625	20
21	.7980673	3.9521453	.8151909	4.4109903	.8323709	4.9655504	21
22	.7983522	3.9591421	.8154768	4.4193737	.8326577	4.9757737	22
23	.7986371	3.9661591	.8157627	4.4277835	.8329444	4.9860326	23
24	.7989221	3.9731964	.8160486	4.4362199	.8332313	4.9963274	24
25	.7992070	3.9802541	.8163346	4.4446831	.8335181	5.0066581	25
26	.7994920	3.9873323	.8166205	4.4531731	.8338049	5.0170250	26
27	.7997770	3.9944311	.8169065	4.4616901	.8340918	5.0274282	27
28	.8000620	4.0015505	.8171925	4.4702342	.8343786	5.0378680	28
29	.8003470	4.0086907	.8174785	4.4788056	.8346655	5.0483445	29
30	0.8006321	4.0158517	0.8177645	4.4874043	0.8349524	5.0588580	30
31	.8009171	4.0230337	.8180505	4.4960305	.8352393	5.0694085	31
32	.8012022	4.0302367	.8183365	4.5046843	.8355262	5.0799964	32
33	.8014873	4.0374607	.8186226	4.5133659	.8358132	5.0906219	33
34	.8017724	4.0447060	.8189087	4.5220754	.8361001	5.1012850	34
35	.8020575	4.0519726	.8191948	4.5308129	.8363871	5.1119861	35
36	.8023427	4.0592606	.8194809	4.5395786	.8366740	5.1227253	36
37	.8026278	4.0665701	.8197670	4.5483726	.8369610	5.1335028	37
38	.8029130	4.0739012	.8200531	4.5571951	.8372480	5.1443189	38
39	.8031982	4.0812539	.8203393	4.5660460	.8375350	5.1551736	39
40	0.8034834	4.0886284	0.8206254	4.5749258	0.8378221	5.1660674	40
41	.8037686	4.0960248	.8209116	4.5838343	.8381091	5.1770003	41
42	.8040539	4.1034431	.8211978	4.5927719	.8383962	5.1879725	42
43	.8043391	4.1108835	.8214840	4.6017386	.8386833	5.1989843	43
44	.8046244	4.1183461	.8217702	4.6107345	.8389703	5.2100359	44
45	.8049097	4.1258309	.8220565	4.6197599	.8392574	5.2211275	45
46	.8051950	4.1333381	.8223427	4.6288148	.8395445	5.2322594	46
47	.8054803	4.1408677	.8226290	4.6378995	.8398317	5.2434316	47
48	.8057656	4.1484199	.8229153	4.6470140	.8401188	5.2546446	48
49	.8060510	4.1559948	.8232016	4.6561584	.8404060	5.2658984	49
50	0.8063364	4.1635924	0.8234879	4.6653331	0.8406931	5.2771933	50
51	.8066218	4.1712128	.8237742	4.6745380	.8409803	5.2885295	51
52	.8069072	4.1788563	.8240605	4.6837734	.8412675	5.2999073	52
53	.8071926	4.1865228	.8243469	4.6930393	.8415547	5.3113269	53
54	.8074780	4.1942125	.8246333	4.7023360	.8418419	5.3227884	54
55	.8077635	4.2019254	.8249197	4.7116636	.8421292	5.3342923	55
56	.8080490	4.2096618	.8252061	4.7210223	.8424164	5.3458386	56
57	.8083344	4.2174216	.8254925	4.7304121	.8427037	5.3574276	57
58	.8086199	4.2252050	.8257789	4.7398333	.8429909	5.3690595	58
59	.8089055	4.2330121	.8260654	4.7492861	.8432782	5.3807347	59
60	0.8091910	4.2408431	0.8263518	4.7587705	0.8435655	5.3924532	60

	81°		82°		83°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.8435655	5.3924532	0.8608269	6.1852965	0.8781307	7.2055090	0
1	.8438528	5.4042154	.8611150	6.2001996	.8784194	7.2249952	1
2	.8441402	5.4160216	.8614030	6.2151653	.8787081	7.2445748	2
3	.8444275	5.4278719	.8616911	6.2301940	.8789969	7.2642485	3
4	.8447149	5.4397666	.8619792	6.2452859	.8792856	7.2840171	4
5	.8450022	5.4517059	.8622673	6.2604417	.8795744	7.3038812	5
6	.8452896	5.4636901	.8625555	6.2756616	.8798632	7.3238415	6
7	.8455770	5.4757195	.8628436	6.2909460	.8801519	7.3438986	7
8	.8458644	5.4877944	.8631317	6.3062954	.8804407	7.3640534	8
9	.8461518	5.4999148	.8634199	6.3217102	.8807296	7.3843065	9
10	0.8464393	5.5120812	0.8637081	6.3371909	0.8810184	7.4046586	10
11	.8467267	5.5242938	.8639962	6.3527377	.8813072	7.4251105	11
12	.8470142	5.5365528	.8642844	6.3683512	.8815960	7.4456629	12
13	.8473016	5.5488586	.8645726	6.3840318	.8818849	7.4663165	13
14	.8475891	5.5612113	.8648608	6.3997798	.8821737	7.4870721	14
15	.8478766	5.5736112	.8651491	6.4155959	.8824626	7.5079304	15
16	.8481641	5.5860587	.8654373	6.4314803	.8827515	7.5288923	16
17	.8484516	5.5985540	.8657256	6.4474335	.8830404	7.5499584	17
18	.8487392	5.6110973	.8660138	6.4634560	.8833293	7.5711295	18
19	.8490267	5.6236890	.8663021	6.4795482	.8836182	7.5924065	19
20	0.8493143	5.6363293	0.8665904	6.4957106	0.8839071	7.6137901	20
21	.8496019	5.6490184	.8668787	6.5119437	.8841960	7.6352812	21
22	.8498894	5.6617568	.8671670	6.5282478	.8844849	7.6568805	22
23	.8501770	5.6745446	.8674553	6.5446236	.8847739	7.6785889	23
24	.8504647	5.6873822	.8677436	6.5610713	.8850628	7.7004071	24
25	.8507523	5.7002699	.8680319	6.5775916	.8853518	7.7223361	25
26	.8510399	5.7132079	.8683203	6.5941849	.8856408	7.7443766	26
27	.8513276	5.7261965	.8686087	6.6108516	.8859298	7.7665295	27
28	.8516152	5.7392360	.8688970	6.6275923	.8862188	7.7887957	28
29	.8519029	5.7523268	.8691854	6.6444075	.8865078	7.8111761	29
30	0.8521906	5.7654691	0.8694738	6.6612976	0.8867968	7.8336715	30
31	.8524783	5.7786632	.8697622	6.6782631	.8870858	7.8562828	31
32	.8527660	5.7919095	.8700506	6.6953047	.8873748	7.8790109	32
33	.8530537	5.8052082	.8703391	6.7124227	.8876639	7.9018567	33
34	.8533415	5.8185597	.8706275	6.7296176	.8879529	7.9248211	34
35	.8536292	5.8319642	.8709159	6.7468901	.8882420	7.9479051	35
36	.8539170	5.8454222	.8712044	6.7642406	.8885311	7.9711095	36
37	.8542047	5.8589338	.8714929	6.7816697	.8888201	7.9944354	37
38	.8544925	5.8724995	.8717814	6.7991778	.8891092	8.0178837	38
39	.8547803	5.8861195	.8720698	6.8167656	.8893983	8.0414553	39
40	0.8550681	5.8997942	0.8723584	6.8344335	0.8896874	8.0651512	40
41	.8553560	5.9135239	.8726469	6.8521821	.8899766	8.0889725	41
42	.8556438	5.9273089	.8729354	6.8700120	.8902657	8.1129200	42
43	.8559316	5.9411496	.8732239	6.8879238	.8905548	8.1369949	43
44	.8562195	5.9550464	.8735125	6.9059179	.8908440	8.1611980	44
45	.8565074	5.9689994	.8738010	6.9239950	.8911331	8.1855305	45
46	.8567953	5.9830092	.8740896	6.9421556	.8914223	8.2099934	46
47	.8570832	5.9970760	.8743782	6.9604003	.8917115	8.2345877	47
48	.8573711	6.0112001	.8746668	6.9787298	.8920006	8.2593145	48
49	.8576590	6.0253820	.8749554	6.9971445	.8922898	8.2841749	49
50	0.8579469	6.0396220	0.8752440	7.0156450	0.8925790	8.3091699	50
51	.8582349	6.0539205	.8755326	7.0342321	.8928682	8.3343006	51
52	.8585228	6.0682777	.8758212	7.0529062	.8931575	8.3595682	52
53	.8588108	6.0826941	.8761099	7.0716681	.8934467	8.3849738	53
54	.8590988	6.0971700	.8763985	7.0905182	.8937359	8.4105184	54
55	.8593868	6.1117059	.8766872	7.1094573	.8940252	8.4362033	55
56	.8596748	6.1263019	.8769759	7.1284860	.8943144	8.4620296	56
57	.8599628	6.1409587	.8772645	7.1476048	.8946037	8.4879984	57
58	.8602508	6.1556764	.8775532	7.1668145	.8948930	8.5141110	58
59	.8605388	6.1704556	.8778419	7.1861157	.8951822	8.5403686	59
60	0.8608269	6.1852965	0.8781307	7.2055090	0.8954715	8.5667722	60

	84°		85°		86°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.8954715	8.5667722	0.9128443	10.473713	0.9302435	13.335587	0
1	.8957608	8.5933233	.9131340	10.511990	.9305337	13.395471	1
2	.8960501	8.6200229	.9134238	10.550523	.9308239	13.455859	2
3	.8963395	8.6468724	.9137136	10.589316	.9311141	13.516757	3
4	.8966288	8.6738730	.9140034	10.628372	.9314043	13.578172	4
5	.8969181	8.7010260	.9142933	10.667693	.9316945	13.640109	5
6	.8972075	8.7283327	.9145831	10.707282	.9319847	13.702576	6
7	.8974968	8.7557944	.9148729	10.747141	.9322749	13.765580	7
8	.8977862	8.7834124	.9151627	10.787274	.9325651	13.829128	8
9	.8980755	8.8111880	.9154526	10.827683	.9328554	13.893226	9
10	0.8983649	8.8391227	0.9157424	10.868370	0.9331456	13.957882	10
11	.8986543	8.8672176	.9160323	10.909340	.9334359	14.023103	11
12	.8989437	8.8954744	.9163222	10.950595	.9337261	14.088896	12
13	.8992331	8.9238943	.9166120	10.992137	.9340164	14.155270	13
14	.8995225	8.9524787	.9169019	11.033970	.9343066	14.222231	14
15	.8998119	8.9812291	.9171918	11.076098	.9345969	14.289788	15
16	.9001014	9.010147	.9174817	11.118522	.9348871	14.357949	16
17	.9003908	9.039234	.9177716	11.161246	.9351774	14.426721	17
18	.9006803	9.068491	.9180615	11.204274	.9354677	14.496114	18
19	.9009697	9.097920	.9183514	11.247608	.9357580	14.566135	19
20	0.9012592	9.127522	0.9186413	11.291252	0.9360483	14.636793	20
21	.9015486	9.157300	.9189313	11.335210	.9363386	14.708096	21
22	.9018381	9.187254	.9192212	11.379484	.9366289	14.780054	22
23	.9021276	9.217386	.9195111	11.424078	.9369192	14.852676	23
24	.9024171	9.247697	.9198011	11.468995	.9372095	14.925971	24
25	.9027066	9.278190	.9200910	11.514240	.9374998	14.999948	25
26	.9029961	9.308866	.9203810	11.559815	.9377901	15.074617	26
27	.9032856	9.339726	.9206710	11.605724	.9380804	15.149987	27
28	.9035752	9.370772	.9209609	11.651971	.9383708	15.226069	28
29	.9038647	9.402007	.9212509	11.698560	.9386611	15.302873	29
30	0.9041542	9.433431	0.9215409	11.745495	0.9389515	15.380408	30
31	.9044438	9.465046	.9218309	11.792779	.9392418	15.458686	31
32	.9047334	9.496854	.9221209	11.840416	.9395322	15.537717	32
33	.9050229	9.528857	.9224109	11.888410	.9398225	15.617512	33
34	.9053125	9.561057	.9227009	11.936765	.9401129	15.698082	34
35	.9056021	9.593455	.9229909	11.985486	.9404033	15.779439	35
36	.9058917	9.626054	.9232810	12.034576	.9406936	15.861594	36
37	.9061813	9.658854	.9235710	12.084040	.9409840	15.944559	37
38	.9064709	9.691859	.9238610	12.133882	.9412744	16.028346	38
39	.9067605	9.725070	.9241511	12.184106	.9415648	16.112966	39
40	0.9070501	9.758488	0.9244411	12.234717	0.9418552	16.198434	40
41	.9073398	9.792117	.9247312	12.285719	.9421456	16.284761	41
42	.9076294	9.825957	.9250213	12.337116	.9424360	16.371960	42
43	.9079191	9.860011	.9253113	12.388914	.9427264	16.460046	43
44	.9082087	9.894281	.9256014	12.441118	.9430168	16.549030	44
45	.9084984	9.928768	.9258915	12.493731	.9433072	16.638928	45
46	.9087881	9.963476	.9261816	12.546758	.9435976	16.729753	46
47	.9090777	9.998406	.9264717	12.600205	.9438881	16.821520	47
48	.9093674	10.033560	.9267618	12.654077	.9441785	16.914243	48
49	.9096571	10.068940	.9270519	12.708379	.9444689	17.007937	49
50	0.9099468	10.104549	0.9273420	12.763115	0.9447594	17.102619	50
51	.9102365	10.140389	.9276322	12.818291	.9450498	17.198303	51
52	.9105262	10.176462	.9279223	12.873913	.9453403	17.295005	52
53	.9108160	10.212770	.9282124	12.929985	.9456307	17.392742	53
54	.9111057	10.249316	.9285026	12.986514	.9459212	17.491530	54
55	.9113954	10.286101	.9287927	13.043504	.9462117	17.591387	55
56	.9116852	10.323129	.9290829	13.100963	.9465021	17.692330	56
57	.9119749	10.360402	.9293730	13.158894	.9467926	17.794377	57
58	.9122647	10.397922	.9296632	13.217304	.9470831	17.897545	58
59	.9125545	10.435692	.9299533	13.276200	.9473736	18.001854	59
60	0.9128443	10.473713	0.9302435	13.335587	0.9476640	18.107323	60

	87°		88°		89°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	0.9476640	18.107323	0.9651005	27.653708	0.9825476	56.298688	0
1	.9479545	18.213970	.9653912	27.894398	.9828384	57.269755	1
2	.9482450	18.321816	.9656819	28.139169	.9831293	58.274308	2
3	.9485355	18.430882	.9659726	28.388124	.9834201	59.314110	3
4	.9488260	18.541187	.9662634	28.641373	.9837110	60.391050	4
5	.9491165	18.652754	.9665541	28.899026	.9840018	61.507153	5
6	.9494071	18.765604	.9668448	29.161201	.9842927	62.664595	6
7	.9496976	18.879758	.9671356	29.428017	.9845835	63.865716	7
8	.9499881	18.995241	.9674263	29.699598	.9848744	65.113036	8
9	.9502786	19.112075	.9677170	29.976074	.9851652	66.409272	9
10	0.9505692	19.230284	0.9680078	30.257577	0.9854561	67.757360	10
11	.9508597	19.349893	.9682985	30.544246	.9857470	69.160474	11
12	.9511502	19.470926	.9685892	30.836225	.9860378	70.622052	12
13	.9514408	19.593409	.9688800	31.133663	.9863287	72.145827	13
14	.9517313	19.717368	.9691707	31.436713	.9866195	73.735856	14
15	.9520219	19.842830	.9694615	31.745537	.9869104	75.396554	15
16	.9523124	19.969824	.9697522	32.060300	.9872013	77.132742	16
17	.9526030	20.098376	.9700430	32.381176	.9874921	78.949684	17
18	.9528935	20.228515	.9703338	32.708345	.9877830	80.853150	18
19	.9531841	20.360272	.9706245	33.041994	.9880739	82.849470	19
20	0.9534747	20.493676	0.9709153	33.382316	0.9883647	84.945609	20
21	.9537653	20.628759	.9712060	33.729515	.9886556	87.149244	21
22	.9540558	20.765553	.9714968	34.083800	.9889465	89.468863	22
23	.9543464	20.904090	.9717876	34.445391	.9892373	91.913869	23
24	.9546370	21.044403	.9720784	34.814517	.9895282	94.494711	24
25	.9549276	21.186528	.9723691	35.191414	.9898191	97.223033	25
26	.9552182	21.330499	.9726599	35.576332	.9901100	100.11185	26
27	.9555088	21.476353	.9729507	35.969528	.9904008	103.17574	27
28	.9557994	21.624126	.9732415	36.371273	.9906917	106.43114	28
29	.9560900	21.773857	.9735323	36.781849	.9909826	109.89656	29
30	0.9563806	21.925586	0.9738231	37.201550	0.9912735	113.59301	30
31	.9566712	22.079351	.9741138	37.630683	.9915643	117.54440	31
32	.9569618	22.235196	.9744046	38.069571	.9918552	121.77803	32
33	.9572525	22.393161	.9746954	38.518549	.9921461	126.32526	33
34	.9575431	22.553291	.9749862	38.977969	.9924370	131.22229	34
35	.9578337	22.715630	.9752770	39.448201	.9927279	136.51108	35
36	.9581243	22.880224	.9755678	39.929630	.9930187	142.24061	36
37	.9584150	23.047121	.9758586	40.422660	.9933096	148.46837	37
38	.9587056	23.216370	.9761494	40.927717	.9936005	155.26228	38
39	.9589963	23.388020	.9764402	41.445245	.9938914	162.70325	39
40	0.9592869	23.562123	0.9767310	41.975713	0.9941823	170.88831	40
41	.9595776	23.738731	.9770219	42.519612	.9944732	179.93496	41
42	.9598682	23.917900	.9773127	43.077458	.9947640	189.98680	42
43	.9601589	24.099685	.9776035	43.649795	.9950549	201.22122	43
44	.9604495	24.284144	.9778943	44.237195	.9953458	213.85995	44
45	.9607402	24.471337	.9781851	44.840260	.9956367	228.18385	45
46	.9610308	24.661324	.9784759	45.459625	.9959276	244.55402	46
47	.9613215	24.854169	.9787668	46.095961	.9962185	263.44269	47
48	.9616122	25.049937	.9790576	46.749974	.9965093	285.47948	48
49	.9619029	25.248694	.9793484	47.422411	.9968002	311.52297	49
50	0.9621935	25.450510	0.9796392	48.114062	0.9970911	342.77516	50
51	.9624842	25.655455	.9799301	48.825762	.9973820	380.97230	51
52	.9627749	25.863603	.9802209	49.558396	.9976729	428.71873	52
53	.9630656	26.075030	.9805117	50.312902	.9979638	490.10702	53
54	.9633563	26.289814	.9808026	51.090272	.9982547	571.95809	54
55	.9636470	26.508035	.9810934	51.891564	.9985456	686.54960	55
56	.9639377	26.729777	.9813842	52.717896	.9988364	858.43689	56
57	.9642284	26.955125	.9816751	53.570464	.9991273	1144.9157	57
58	.9645191	27.184168	.9819659	54.450534	.9994182	1717.8735	58
59	.9648098	27.416997	.9822568	55.359462	.9997091	3436.7468	59
60	0.9651005	27.653708	0.9825476	56.298688	1.0000000	Infinite	60

NATURAL SECANTS							
	0°	1°	2°	3°	4°	5°	
0	1.0000000	1.0001523	1.0006095	1.0013723	1.0024419	1.0038198	60
1	1.0000000	1.0001574	1.0006198	1.0013877	1.0024623	1.0038454	59
2	1.0000002	1.0001627	1.0006300	1.0014030	1.0024829	1.0038711	58
3	1.0000004	1.0001679	1.0006404	1.0014185	1.0025035	1.0038969	57
4	1.0000007	1.0001733	1.0006509	1.0014341	1.0025241	1.0039227	56
5	1.0000011	1.0001788	1.0006614	1.0014497	1.0025449	1.0039486	55
6	1.0000015	1.0001843	1.0006721	1.0014655	1.0025658	1.0039747	54
7	1.0000021	1.0001900	1.0006828	1.0014813	1.0025867	1.0040008	53
8	1.0000027	1.0001957	1.0006936	1.0014972	1.0026078	1.0040270	52
9	1.0000034	1.0002015	1.0007045	1.0015132	1.0026289	1.0040533	51
10	1.0000042	1.0002073	1.0007154	1.0015293	1.0026501	1.0040796	50
11	1.0000051	1.0002133	1.0007265	1.0015454	1.0026714	1.0041061	49
12	1.0000061	1.0002194	1.0007376	1.0015617	1.0026928	1.0041326	48
13	1.0000072	1.0002255	1.0007489	1.0015780	1.0027142	1.0041592	47
14	1.0000083	1.0002317	1.0007602	1.0015944	1.0027358	1.0041859	46
15	1.0000095	1.0002380	1.0007716	1.0016109	1.0027574	1.0042127	45
16	1.0000108	1.0002444	1.0007830	1.0016275	1.0027791	1.0042396	44
17	1.0000122	1.0002509	1.0007946	1.0016442	1.0028009	1.0042666	43
18	1.0000137	1.0002575	1.0008063	1.0016609	1.0028228	1.0042937	42
19	1.0000153	1.0002641	1.0008180	1.0016778	1.0028448	1.0043208	41
20	1.0000169	1.0002708	1.0008298	1.0016947	1.0028669	1.0043480	40
21	1.0000187	1.0002776	1.0008417	1.0017117	1.0028890	1.0043753	39
22	1.0000205	1.0002845	1.0008537	1.0017288	1.0029112	1.0044028	38
23	1.0000224	1.0002915	1.0008658	1.0017460	1.0029336	1.0044302	37
24	1.0000244	1.0002986	1.0008779	1.0017633	1.0029560	1.0044578	36
25	1.0000264	1.0003058	1.0008902	1.0017806	1.0029785	1.0044855	35
26	1.0000286	1.0003130	1.0009025	1.0017981	1.0030010	1.0045132	34
27	1.0000308	1.0003203	1.0009149	1.0018156	1.0030237	1.0045411	33
28	1.0000332	1.0003277	1.0009274	1.0018332	1.0030464	1.0045690	32
29	1.0000356	1.0003352	1.0009400	1.0018509	1.0030693	1.0045970	31
30	1.0000381	1.0003428	1.0009527	1.0018687	1.0030922	1.0046251	30
31	1.0000407	1.0003505	1.0009654	1.0018866	1.0031152	1.0046533	29
32	1.0000433	1.0003582	1.0009783	1.0019045	1.0031383	1.0046815	28
33	1.0000461	1.0003660	1.0009912	1.0019225	1.0031615	1.0047099	27
34	1.0000489	1.0003739	1.0010042	1.0019407	1.0031847	1.0047383	26
35	1.0000518	1.0003820	1.0010173	1.0019589	1.0032081	1.0047669	25
36	1.0000548	1.0003900	1.0010305	1.0019772	1.0032315	1.0047955	24
37	1.0000579	1.0003982	1.0010438	1.0019956	1.0032551	1.0048242	23
38	1.0000611	1.0004065	1.0010571	1.0020140	1.0032787	1.0048530	22
39	1.0000644	1.0004148	1.0010705	1.0020326	1.0033024	1.0048819	21
40	1.0000677	1.0004232	1.0010841	1.0020512	1.0033261	1.0049108	20
41	1.0000711	1.0004317	1.0010977	1.0020699	1.0033500	1.0049399	19
42	1.0000746	1.0004403	1.0011114	1.0020887	1.0033740	1.0049690	18
43	1.0000782	1.0004490	1.0011251	1.0021076	1.0033980	1.0049982	17
44	1.0000819	1.0004578	1.0011390	1.0021266	1.0034221	1.0050275	16
45	1.0000857	1.0004666	1.0011529	1.0021457	1.0034463	1.0050569	15
46	1.0000895	1.0004756	1.0011670	1.0021648	1.0034706	1.0050864	14
47	1.0000935	1.0004846	1.0011811	1.0021841	1.0034950	1.0051160	13
48	1.0000975	1.0004937	1.0011953	1.0022034	1.0035195	1.0051456	12
49	1.0001016	1.0005029	1.0012096	1.0022228	1.0035440	1.0051754	11
50	1.0001058	1.0005121	1.0012239	1.0022423	1.0035687	1.0052052	10
51	1.0001101	1.0005215	1.0012384	1.0022619	1.0035934	1.0052351	9
52	1.0001144	1.0005309	1.0012529	1.0022815	1.0036182	1.0052651	8
53	1.0001189	1.0005405	1.0012676	1.0023013	1.0036431	1.0052952	7
54	1.0001234	1.0005501	1.0012823	1.0023211	1.0036681	1.0053254	6
55	1.0001280	1.0005598	1.0012971	1.0023410	1.0036932	1.0053557	5
56	1.0001327	1.0005696	1.0013120	1.0023610	1.0037183	1.0053860	4
57	1.0001375	1.0005794	1.0013269	1.0023811	1.0037436	1.0054164	3
58	1.0001423	1.0005894	1.0013420	1.0024013	1.0037689	1.0054470	2
59	1.0001473	1.0005994	1.0013571	1.0024216	1.0037943	1.0054776	1
60	1.0001523	1.0006095	1.0013723	1.0024419	1.0038198	1.0055083	0
	89°	88°	87°	86°	85°	84°	
NATURAL COSECANTS							

NATURAL SECANTS

	6°	7°	8°	9°	10°	11°	
0	1.0055083	1.0075098	1.0098276	1.0124651	1.0154266	1.0187167	60
1	1.0055391	1.0075459	1.0098689	1.0125118	1.0154787	1.0187743	59
2	1.0055699	1.0075820	1.0099103	1.0125586	1.0155310	1.0188321	58
3	1.0056009	1.0076182	1.0099518	1.0126055	1.0155833	1.0188899	57
4	1.0056319	1.0076545	1.0099934	1.0126524	1.0156357	1.0189478	56
5	1.0056631	1.0076908	1.0100351	1.0126995	1.0156882	1.0190059	55
6	1.0056943	1.0077273	1.0100769	1.0127466	1.0157408	1.0190640	54
7	1.0057256	1.0077639	1.0101187	1.0127939	1.0157934	1.0191222	53
8	1.0057570	1.0078005	1.0101607	1.0128412	1.0158462	1.0191805	52
9	1.0057885	1.0078372	1.0102027	1.0128886	1.0158991	1.0192389	51
10	1.0058200	1.0078741	1.0102449	1.0129361	1.0159520	1.0192973	50
11	1.0058517	1.0079110	1.0102871	1.0129837	1.0160050	1.0193559	49
12	1.0058834	1.0079480	1.0103294	1.0130314	1.0160582	1.0194146	48
13	1.0059153	1.0079851	1.0103718	1.0130791	1.0161114	1.0194734	47
14	1.0059472	1.0080222	1.0104143	1.0131270	1.0161647	1.0195322	46
15	1.0059792	1.0080595	1.0104568	1.0131750	1.0162181	1.0195912	45
16	1.0060113	1.0080968	1.0104995	1.0132230	1.0162716	1.0196502	44
17	1.0060435	1.0081343	1.0105422	1.0132711	1.0163252	1.0197093	43
18	1.0060757	1.0081718	1.0105851	1.0133194	1.0163789	1.0197686	42
19	1.0061081	1.0082094	1.0106280	1.0133677	1.0164327	1.0198279	41
20	1.0061405	1.0082471	1.0106710	1.0134161	1.0164865	1.0198873	40
21	1.0061731	1.0082849	1.0107141	1.0134646	1.0165405	1.0199468	39
22	1.0062057	1.0083228	1.0107573	1.0135132	1.0165946	1.0200064	38
23	1.0062384	1.0083607	1.0108006	1.0135618	1.0166487	1.0200661	37
24	1.0062712	1.0083988	1.0108440	1.0136106	1.0167029	1.0201259	36
25	1.0063040	1.0084369	1.0108875	1.0136595	1.0167573	1.0201858	35
26	1.0063370	1.0084752	1.0109310	1.0137084	1.0168117	1.0202457	34
27	1.0063701	1.0085135	1.0109747	1.0137574	1.0168662	1.0203058	33
28	1.0064032	1.0085519	1.0110184	1.0138066	1.0169208	1.0203660	32
29	1.0064364	1.0085904	1.0110622	1.0138558	1.0169755	1.0204262	31
30	1.0064697	1.0086290	1.0111061	1.0139051	1.0170303	1.0204866	30
31	1.0065031	1.0086676	1.0111501	1.0139545	1.0170851	1.0205470	29
32	1.0065366	1.0087064	1.0111942	1.0140040	1.0171401	1.0206075	28
33	1.0065702	1.0087452	1.0112384	1.0140536	1.0171952	1.0206682	27
34	1.0066039	1.0087842	1.0112827	1.0141032	1.0172503	1.0207289	26
35	1.0066376	1.0088232	1.0113270	1.0141530	1.0173056	1.0207897	25
36	1.0066714	1.0088623	1.0113715	1.0142029	1.0173609	1.0208506	24
37	1.0067054	1.0089015	1.0114160	1.0142528	1.0174163	1.0209116	23
38	1.0067394	1.0089408	1.0114606	1.0143028	1.0174719	1.0209727	22
39	1.0067735	1.0089802	1.0115054	1.0143530	1.0175275	1.0210339	21
40	1.0068077	1.0090196	1.0115502	1.0144032	1.0175832	1.0210952	20
41	1.0068419	1.0090592	1.0115951	1.0144535	1.0176390	1.0211566	19
42	1.0068763	1.0090988	1.0116400	1.0145039	1.0176949	1.0212180	18
43	1.0069108	1.0091386	1.0116851	1.0145544	1.0177509	1.0212796	17
44	1.0069453	1.0091784	1.0117303	1.0146050	1.0178069	1.0213413	16
45	1.0069799	1.0092183	1.0117755	1.0146556	1.0178631	1.0214030	15
46	1.0070146	1.0092583	1.0118209	1.0147064	1.0179194	1.0214649	14
47	1.0070494	1.0092984	1.0118663	1.0147572	1.0179757	1.0215268	13
48	1.0070843	1.0093386	1.0119118	1.0148082	1.0180321	1.0215888	12
49	1.0071193	1.0093788	1.0119575	1.0148592	1.0180887	1.0216510	11
50	1.0071544	1.0094192	1.0120032	1.0149103	1.0181453	1.0217132	10
51	1.0071895	1.0094596	1.0120489	1.0149616	1.0182020	1.0217755	9
52	1.0072248	1.0095001	1.0120948	1.0150129	1.0182588	1.0218379	8
53	1.0072601	1.0095408	1.0121408	1.0150643	1.0183158	1.0219004	7
54	1.0072955	1.0095815	1.0121869	1.0151158	1.0183728	1.0219630	6
55	1.0073310	1.0096223	1.0122330	1.0151673	1.0184298	1.0220257	5
56	1.0073666	1.0096631	1.0122793	1.0152190	1.0184870	1.0220885	4
57	1.0074023	1.0097041	1.0123256	1.0152708	1.0185443	1.0221514	3
58	1.0074380	1.0097452	1.0123720	1.0153226	1.0186017	1.0222144	2
59	1.0074739	1.0097863	1.0124185	1.0153746	1.0186591	1.0222774	1
60	1.0075098	1.0098276	1.0124651	1.0154266	1.0187167	1.0223406	0
	83°	82°	81°	80°	79°	78°	

NATURAL COSECANTS

NATURAL SECANTS							
	12°	13°	14°	15°	16°	17°	
0	1.0223406	1.0263041	1.0306136	1.0352762	1.0402994	1.0456918	60
1	1.0224039	1.0263731	1.0306884	1.0353569	1.0403863	1.0457848	59
2	1.0224672	1.0264421	1.0307633	1.0354378	1.0404732	1.0458780	58
3	1.0225307	1.0265113	1.0308383	1.0355187	1.0405602	1.0459712	57
4	1.0225942	1.0265806	1.0309134	1.0355998	1.0406473	1.0460646	56
5	1.0226578	1.0266499	1.0309886	1.0356809	1.0407346	1.0461581	55
6	1.0227216	1.0267194	1.0310639	1.0357621	1.0408219	1.0462516	54
7	1.0227854	1.0267889	1.0311393	1.0358435	1.0409094	1.0463453	53
8	1.0228493	1.0268586	1.0312147	1.0359249	1.0409969	1.0464391	52
9	1.0229133	1.0269283	1.0312903	1.0360065	1.0410845	1.0465330	51
10	1.0229774	1.0269982	1.0313660	1.0360881	1.0411723	1.0466270	50
11	1.0230416	1.0270681	1.0314418	1.0361699	1.0412601	1.0467211	49
12	1.0231059	1.0271381	1.0315177	1.0362517	1.0413481	1.0468153	48
13	1.0231703	1.0272082	1.0315936	1.0363337	1.0414362	1.0469096	47
14	1.0232348	1.0272785	1.0316697	1.0364157	1.0415243	1.0470040	46
15	1.0232994	1.0273488	1.0317459	1.0364979	1.0416126	1.0470986	45
16	1.0233641	1.0274192	1.0318222	1.0365801	1.0417009	1.0471932	44
17	1.0234288	1.0274897	1.0318985	1.0366625	1.0417894	1.0472879	43
18	1.0234937	1.0275603	1.0319750	1.0367449	1.0418780	1.0473828	42
19	1.0235587	1.0276310	1.0320516	1.0368275	1.0419667	1.0474777	41
20	1.0236237	1.0277018	1.0321282	1.0369101	1.0420554	1.0475728	40
21	1.0236889	1.0277727	1.0322050	1.0369929	1.0421443	1.0476679	39
22	1.0237541	1.0278437	1.0322818	1.0370757	1.0422333	1.0477632	38
23	1.0238195	1.0279148	1.0323588	1.0371587	1.0423224	1.0478586	37
24	1.0238849	1.0279860	1.0324359	1.0372417	1.0424116	1.0479540	36
25	1.0239504	1.0280573	1.0325130	1.0373249	1.0425009	1.0480496	35
26	1.0240161	1.0281287	1.0325903	1.0374082	1.0425903	1.0481453	34
27	1.0240818	1.0282002	1.0326676	1.0374915	1.0426798	1.0482411	33
28	1.0241476	1.0282717	1.0327451	1.0375750	1.0427694	1.0483370	32
29	1.0242135	1.0283434	1.0328227	1.0376585	1.0428591	1.0484330	31
30	1.0242795	1.0284152	1.0329003	1.0377422	1.0429489	1.0485291	30
31	1.0243456	1.0284871	1.0329781	1.0378260	1.0430388	1.0486253	29
32	1.0244118	1.0285590	1.0330559	1.0379098	1.0431289	1.0487217	28
33	1.0244781	1.0286311	1.0331339	1.0379938	1.0432190	1.0488181	27
34	1.0245445	1.0287033	1.0332119	1.0380779	1.0433092	1.0489146	26
35	1.0246110	1.0287755	1.0332901	1.0381621	1.0433995	1.0490113	25
36	1.0246776	1.0288479	1.0333683	1.0382463	1.0434900	1.0491080	24
37	1.0247442	1.0289203	1.0334467	1.0383307	1.0435805	1.0492049	23
38	1.0248110	1.0289929	1.0335251	1.0384152	1.0436712	1.0493019	22
39	1.0248779	1.0290655	1.0336037	1.0384998	1.0437619	1.0493989	21
40	1.0249448	1.0291383	1.0336823	1.0385844	1.0438528	1.0494961	20
41	1.0250119	1.0292111	1.0337611	1.0386692	1.0439437	1.0495934	19
42	1.0250790	1.0292840	1.0338399	1.0387541	1.0440348	1.0496908	18
43	1.0251463	1.0293571	1.0339188	1.0388391	1.0441259	1.0497883	17
44	1.0252136	1.0294302	1.0339979	1.0389242	1.0442172	1.0498859	16
45	1.0252811	1.0295034	1.0340770	1.0390094	1.0443086	1.0499836	15
46	1.0253486	1.0295768	1.0341563	1.0390947	1.0444001	1.0500815	14
47	1.0254162	1.0296502	1.0342356	1.0391800	1.0444917	1.0501794	13
48	1.0254839	1.0297237	1.0343151	1.0392655	1.0445833	1.0502774	12
49	1.0255518	1.0297973	1.0343946	1.0393511	1.0446751	1.0503756	11
50	1.0256197	1.0298711	1.0344743	1.0394368	1.0447670	1.0504738	10
51	1.0256877	1.0299449	1.0345540	1.0395226	1.0448590	1.0505722	9
52	1.0257558	1.0300188	1.0346338	1.0396085	1.0449511	1.0506706	8
53	1.0258240	1.0300928	1.0347138	1.0396945	1.0450433	1.0507692	7
54	1.0258923	1.0301669	1.0347938	1.0397806	1.0451357	1.0508679	6
55	1.0259607	1.0302411	1.0348740	1.0398669	1.0452281	1.0509667	5
56	1.0260292	1.0303154	1.0349542	1.0399532	1.0453206	1.0510656	4
57	1.0260978	1.0303898	1.0350346	1.0400396	1.0454132	1.0511646	3
58	1.0261665	1.0304643	1.0351150	1.0401261	1.0455060	1.0512637	2
59	1.0262352	1.0305389	1.0351955	1.0402127	1.0455988	1.0513629	1
60	1.0263041	1.0306136	1.0352762	1.0402994	1.0456918	1.0514622	0
	77°	76°	75°	74°	73°	72°	
NATURAL COSECANTS							

NATURAL SECANTS

	18°	19°	20°	21°	22°	23°	
0	1.0514622	1.0576207	1.0641778	1.0711450	1.0785347	1.0863604	60
1	1.0515617	1.0577267	1.0642905	1.0712647	1.0786616	1.0864946	59
2	1.0516612	1.0578328	1.0644033	1.0713844	1.0787885	1.0866289	58
3	1.0517608	1.0579390	1.0645163	1.0715043	1.0789156	1.0867634	57
4	1.0518606	1.0580453	1.0646294	1.0716244	1.0790427	1.0868979	56
5	1.0519605	1.0581517	1.0647425	1.0717445	1.0791700	1.0870326	55
6	1.0520604	1.0582583	1.0648558	1.0718647	1.0792975	1.0871675	54
7	1.0521605	1.0583649	1.0649693	1.0719851	1.0794250	1.0873024	53
8	1.0522607	1.0584717	1.0650828	1.0721056	1.0795527	1.0874375	52
9	1.0523610	1.0585786	1.0651964	1.0722262	1.0796805	1.0875727	51
10	1.0524614	1.0586855	1.0653102	1.0723469	1.0798084	1.0877080	50
11	1.0525619	1.0587926	1.0654240	1.0724678	1.0799364	1.0878433	49
12	1.0526625	1.0588999	1.0655380	1.0725887	1.0800646	1.0879791	48
13	1.0527633	1.0590072	1.0656521	1.0727098	1.0801928	1.0881148	47
14	1.0528641	1.0591146	1.0657663	1.0728310	1.0803212	1.0882506	46
15	1.0529651	1.0592221	1.0658807	1.0729523	1.0804497	1.0883866	45
16	1.0530661	1.0593298	1.0659951	1.0730737	1.0805784	1.0885226	44
17	1.0531673	1.0594376	1.0661097	1.0731953	1.0807071	1.0886589	43
18	1.0532686	1.0595454	1.0662243	1.0733170	1.0808360	1.0887952	42
19	1.0533699	1.0596534	1.0663391	1.0734388	1.0809650	1.0889317	41
20	1.0534714	1.0597615	1.0664540	1.0735607	1.0810942	1.0890682	40
21	1.0535730	1.0598697	1.0665690	1.0736827	1.0812234	1.0892050	39
22	1.0536747	1.0599781	1.0666842	1.0738048	1.0813528	1.0893418	38
23	1.0537765	1.0600865	1.0667994	1.0739271	1.0814823	1.0894788	37
24	1.0538785	1.0601951	1.0669148	1.0740495	1.0816119	1.0896159	36
25	1.0539805	1.0603037	1.0670302	1.0741720	1.0817417	1.0897531	35
26	1.0540826	1.0604125	1.0671458	1.0742946	1.0818715	1.0898904	34
27	1.0541849	1.0605214	1.0672615	1.0744173	1.0820015	1.0900279	33
28	1.0542873	1.0606304	1.0673774	1.0745402	1.0821316	1.0901655	32
29	1.0543897	1.0607395	1.0674933	1.0746631	1.0822618	1.0903032	31
30	1.0544923	1.0608487	1.0676094	1.0747862	1.0823922	1.0904411	30
31	1.0545950	1.0609580	1.0677255	1.0749095	1.0825227	1.0905791	29
32	1.0546978	1.0610675	1.0678418	1.0750328	1.0826533	1.0907172	28
33	1.0548007	1.0611770	1.0679582	1.0751562	1.0827840	1.0908554	27
34	1.0549037	1.0612867	1.0680747	1.0752798	1.0829149	1.0909938	26
35	1.0550068	1.0613965	1.0681914	1.0754035	1.0830458	1.0911323	25
36	1.0551101	1.0615064	1.0683081	1.0755273	1.0831769	1.0912709	24
37	1.0552134	1.0616164	1.0684250	1.0756512	1.0833081	1.0914097	23
38	1.0553169	1.0617265	1.0685420	1.0757753	1.0834395	1.0915485	22
39	1.0554204	1.0618367	1.0686591	1.0758995	1.0835709	1.0916876	21
40	1.0555241	1.0619471	1.0687763	1.0760237	1.0837025	1.0918267	20
41	1.0556279	1.0620575	1.0688936	1.0761481	1.0838342	1.0919659	19
42	1.0557318	1.0621681	1.0690110	1.0762727	1.0839661	1.0921053	18
43	1.0558358	1.0622788	1.0691286	1.0763973	1.0840980	1.0922448	17
44	1.0559399	1.0623896	1.0692463	1.0765221	1.0842301	1.0923845	16
45	1.0560441	1.0625005	1.0693641	1.0766470	1.0843623	1.0925243	15
46	1.0561485	1.0626115	1.0694820	1.0767720	1.0844947	1.0926642	14
47	1.0562529	1.0627227	1.0696000	1.0768971	1.0846271	1.0928042	13
48	1.0563575	1.0628339	1.0697182	1.0770224	1.0847597	1.0929444	12
49	1.0564621	1.0629453	1.0698364	1.0771477	1.0848924	1.0930846	11
50	1.0565669	1.0630568	1.0699548	1.0772732	1.0850252	1.0932251	10
51	1.0566718	1.0631684	1.0700733	1.0773988	1.0851582	1.0933656	9
52	1.0567768	1.0632801	1.0701919	1.0775246	1.0852913	1.0935063	8
53	1.0568819	1.0633919	1.0703106	1.0776504	1.0854245	1.0936471	7
54	1.0569871	1.0635038	1.0704295	1.0777764	1.0855578	1.0937880	6
55	1.0570924	1.0636158	1.0705484	1.0779025	1.0856912	1.0939291	5
56	1.0571978	1.0637280	1.0706675	1.0780287	1.0858248	1.0940702	4
57	1.0573034	1.0638403	1.0707867	1.0781550	1.0859585	1.0942116	3
58	1.0574090	1.0639527	1.0709060	1.0782815	1.0860924	1.0943530	2
59	1.0575148	1.0640652	1.0710254	1.0784080	1.0862263	1.0944946	1
60	1.0576207	1.0641778	1.0711450	1.0785347	1.0863604	1.0946363	0
	71°	70°	69°	68°	67°	66°	

NATURAL COSECANTS

	NATURAL SECANTS						
	24°	25°	26°	27°	28°	29°	
0	1.0946363	1.1033779	1.1126019	1.1223262	1.1325701	1.1433541	60
1	1.0947781	1.1035277	1.1127599	1.1224927	1.1327453	1.1435385	59
2	1.0949201	1.1036775	1.1129179	1.1226592	1.1329207	1.1437231	58
3	1.0950622	1.1038275	1.1130761	1.1228259	1.1330962	1.1439078	57
4	1.0952044	1.1039777	1.1132345	1.1229928	1.1332719	1.1440927	56
5	1.0953467	1.1041279	1.1133929	1.1231598	1.1334478	1.1442778	55
6	1.0954892	1.1042783	1.1135516	1.1233269	1.1336238	1.1444630	54
7	1.0956318	1.1044289	1.1137103	1.1234942	1.1337999	1.1446484	53
8	1.0957746	1.1045795	1.1138692	1.1236616	1.1339762	1.1448339	52
9	1.0959174	1.1047303	1.1140282	1.1238292	1.1341527	1.1450196	51
10	1.0960604	1.1048813	1.1141874	1.1239969	1.1343293	1.1452055	50
11	1.0962036	1.1050324	1.1143467	1.1241648	1.1345060	1.1453915	49
12	1.0963468	1.1051836	1.1145062	1.1243328	1.1346829	1.1455776	48
13	1.0964902	1.1053349	1.1146658	1.1245010	1.1348600	1.1457639	47
14	1.0966337	1.1054864	1.1148255	1.1246693	1.1350372	1.1459504	46
15	1.0967774	1.1056380	1.1149854	1.1248377	1.1352146	1.1461371	45
16	1.0969212	1.1057898	1.1151454	1.1250063	1.1353921	1.1463238	44
17	1.0970651	1.1059417	1.1153056	1.1251750	1.1355697	1.1465108	43
18	1.0972091	1.1060937	1.1154659	1.1253439	1.1357475	1.1466979	42
19	1.0973533	1.1062458	1.1156263	1.1255130	1.1359255	1.1468852	41
20	1.0974976	1.1063981	1.1157869	1.1256821	1.1361036	1.1470726	40
21	1.0976420	1.1065506	1.1159476	1.1258514	1.1362819	1.1472602	39
22	1.0977866	1.1067031	1.1161084	1.1260209	1.1364603	1.1474479	38
23	1.0979313	1.1068558	1.1162694	1.1261905	1.1366389	1.1476358	37
24	1.0980761	1.1070087	1.1164306	1.1263603	1.1368176	1.1478239	36
25	1.0982211	1.1071616	1.1165919	1.1265302	1.1369965	1.1480121	35
26	1.0983662	1.1073147	1.1167533	1.1267003	1.1371755	1.1482005	34
27	1.0985114	1.1074680	1.1169148	1.1268705	1.1373547	1.1483890	33
28	1.0986568	1.1076214	1.1170766	1.1270408	1.1375341	1.1485777	32
29	1.0988023	1.1077749	1.1172384	1.1272113	1.1377135	1.1487665	31
30	1.0989479	1.1079285	1.1174004	1.1273819	1.1378932	1.1489555	30
31	1.0990936	1.1080823	1.1175625	1.1275527	1.1380730	1.1491447	29
32	1.0992395	1.1082363	1.1177248	1.1277237	1.1382529	1.1493340	28
33	1.0993855	1.1083903	1.1178872	1.1278948	1.1384330	1.1495235	27
34	1.0995317	1.1085445	1.1180498	1.1280660	1.1386133	1.1497132	26
35	1.0996779	1.1086989	1.1182124	1.1282374	1.1387937	1.1499030	25
36	1.0998243	1.1088533	1.1183753	1.1284089	1.1389742	1.1500930	24
37	1.0999709	1.1090079	1.1185383	1.1285806	1.1391550	1.1502831	23
38	1.1001175	1.1091627	1.1187014	1.1287524	1.1393358	1.1504734	22
39	1.1002644	1.1093176	1.1188647	1.1289244	1.1395169	1.1506638	21
40	1.1004113	1.1094726	1.1190281	1.1290965	1.1396980	1.1508544	20
41	1.1005584	1.1096277	1.1191916	1.1292687	1.1398794	1.1510452	19
42	1.1007056	1.1097830	1.1193553	1.1294412	1.1400608	1.1512361	18
43	1.1008529	1.1099385	1.1195191	1.1296137	1.1402425	1.1514272	17
44	1.1010004	1.1100940	1.1196831	1.1297864	1.1404243	1.1516185	16
45	1.1011480	1.1102498	1.1198472	1.1299593	1.1406062	1.1518099	15
46	1.1012957	1.1104056	1.1200115	1.1301323	1.1407883	1.1520015	14
47	1.1014436	1.1105616	1.1201759	1.1303055	1.1409706	1.1521932	13
48	1.1015916	1.1107177	1.1203405	1.1304788	1.1411530	1.1523851	12
49	1.1017397	1.1108740	1.1205051	1.1306522	1.1413356	1.1525772	11
50	1.1018879	1.1110304	1.1206700	1.1308258	1.1415183	1.1527694	10
51	1.1020363	1.1111869	1.1208350	1.1309996	1.1417012	1.1529618	9
52	1.1021849	1.1113436	1.1210001	1.1311735	1.1418842	1.1531543	8
53	1.1023335	1.1115004	1.1211653	1.1313475	1.1420674	1.1533470	7
54	1.1024823	1.1116573	1.1213308	1.1315217	1.1422507	1.1535399	6
55	1.1026313	1.1118144	1.1214963	1.1316961	1.1424342	1.1537329	5
56	1.1027803	1.1119716	1.1216620	1.1318706	1.1426179	1.1539261	4
57	1.1029295	1.1121290	1.1218278	1.1320452	1.1428017	1.1541195	3
58	1.1030789	1.1122865	1.1219938	1.1322200	1.1429857	1.1543130	2
59	1.1032283	1.1124442	1.1221600	1.1323950	1.1431698	1.1545067	1
60	1.1033779	1.1126019	1.1223262	1.1325701	1.1433541	1.1547005	0
	65°	64°	63°	62°	61°	60°	

NATURAL SECANTS

	30°	31°	32°	33°	34°	35°	
0	1.1547005	1.1666334	1.1791784	1.1923633	1.2062179	1.2207746	60
1	1.1548945	1.1668374	1.1793928	1.1925886	1.2064547	1.2210233	59
2	1.1550887	1.1670416	1.1796074	1.1928142	1.2066917	1.2212723	58
3	1.1552830	1.1672459	1.1798222	1.1930399	1.2069288	1.2215215	57
4	1.1554775	1.1674504	1.1800372	1.1932658	1.2071662	1.2217708	56
5	1.1556722	1.1676551	1.1802523	1.1934918	1.2074037	1.2220204	55
6	1.1558670	1.1678599	1.1804675	1.1937181	1.2076415	1.2222702	54
7	1.1560620	1.1680649	1.1806831	1.1939446	1.2078794	1.2225202	53
8	1.1562572	1.1682701	1.1808988	1.1941712	1.2081175	1.2227703	52
9	1.1564525	1.1684755	1.1811146	1.1943980	1.2083559	1.2230207	51
10	1.1566480	1.1686810	1.1813307	1.1946251	1.2085944	1.2232713	50
11	1.1568436	1.1688867	1.1815469	1.1948523	1.2088331	1.2235222	49
12	1.1570394	1.1690926	1.1817633	1.1950796	1.2090720	1.2237732	48
13	1.1572354	1.1692986	1.1819798	1.1953072	1.2093112	1.2240244	47
14	1.1574315	1.1695048	1.1821966	1.1955350	1.2095505	1.2242758	46
15	1.1576278	1.1697112	1.1824135	1.1957629	1.2097900	1.2245274	45
16	1.1578243	1.1699178	1.1826306	1.1959911	1.2100297	1.2247793	44
17	1.1580209	1.1701245	1.1828479	1.1962194	1.2102696	1.2250313	43
18	1.1582177	1.1703314	1.1830654	1.1964479	1.2105097	1.2252836	42
19	1.1584146	1.1705385	1.1832830	1.1966767	1.2107500	1.2255361	41
20	1.1586118	1.1707457	1.1835008	1.1969056	1.2109905	1.2257887	40
21	1.1588091	1.1709531	1.1837188	1.1971346	1.2112312	1.2260416	39
22	1.1590065	1.1711607	1.1839370	1.1973639	1.2114721	1.2262947	38
23	1.1592041	1.1713685	1.1841554	1.1975934	1.2117132	1.2265480	37
24	1.1594019	1.1715764	1.1843739	1.1978230	1.2119545	1.2268015	36
25	1.1595999	1.1717845	1.1845927	1.1980529	1.2121960	1.2270552	35
26	1.1597980	1.1719928	1.1848116	1.1982829	1.2124377	1.2273091	34
27	1.1599963	1.1722013	1.1850307	1.1985131	1.2126795	1.2275633	33
28	1.1601947	1.1724099	1.1852500	1.1987435	1.2129216	1.2278176	32
29	1.1603933	1.1726187	1.1854694	1.1989741	1.2131639	1.2280722	31
30	1.1605921	1.1728277	1.1856890	1.1992049	1.2134064	1.2283269	30
31	1.1607911	1.1730368	1.1859089	1.1994359	1.2136491	1.2285819	29
32	1.1609902	1.1732462	1.1861280	1.1996671	1.2138920	1.2288371	28
33	1.1611894	1.1734557	1.1863490	1.1998985	1.2141351	1.2290924	27
34	1.1613889	1.1736653	1.1865694	1.2001300	1.2143784	1.2293480	26
35	1.1615885	1.1738752	1.1867900	1.2003618	1.2146218	1.2296039	25
36	1.1617883	1.1740852	1.1870107	1.2005937	1.2148655	1.2298599	24
37	1.1619882	1.1742954	1.1872316	1.2008258	1.2151094	1.2301161	23
38	1.1621883	1.1745058	1.1874527	1.2010582	1.2153535	1.2303725	22
39	1.1623886	1.1747163	1.1876740	1.2012907	1.2155978	1.2306292	21
40	1.1625891	1.1749270	1.1878954	1.2015234	1.2158423	1.2308861	20
41	1.1627897	1.1751379	1.1881171	1.2017563	1.2160870	1.2311432	19
42	1.1629905	1.1753490	1.1883389	1.2019894	1.2163319	1.2314004	18
43	1.1631914	1.1755603	1.1885609	1.2022226	1.2165770	1.2316579	17
44	1.1633925	1.1757717	1.1887831	1.2024561	1.2168223	1.2319156	16
45	1.1635938	1.1759833	1.1890055	1.2026898	1.2170678	1.2321736	15
46	1.1637953	1.1761951	1.1892280	1.2029236	1.2173135	1.2324317	14
47	1.1639969	1.1764070	1.1894508	1.2031577	1.2175594	1.2326900	13
48	1.1641987	1.1766191	1.1896737	1.2033919	1.2178055	1.2329486	12
49	1.1644007	1.1768314	1.1898968	1.2036264	1.2180518	1.2332074	11
50	1.1646028	1.1770439	1.1901201	1.2038610	1.2182983	1.2334664	10
51	1.1648051	1.1772566	1.1903436	1.2040958	1.2185450	1.2337256	9
52	1.1650076	1.1774694	1.1905673	1.2043308	1.2187919	1.2339850	8
53	1.1652102	1.1776824	1.1907911	1.2045660	1.2190390	1.2342446	7
54	1.1654130	1.1778956	1.1910152	1.2048014	1.2192864	1.2345044	6
55	1.1656160	1.1781089	1.1912394	1.2050370	1.2195339	1.2347645	5
56	1.1658191	1.1783225	1.1914638	1.2052728	1.2197816	1.2350248	4
57	1.1660224	1.1785362	1.1916884	1.2055088	1.2200296	1.2352852	3
58	1.1662259	1.1787501	1.1919132	1.2057450	1.2202777	1.2355459	2
59	1.1664296	1.1789642	1.1921381	1.2059814	1.2205260	1.2358069	1
60	1.1666334	1.1791784	1.1923633	1.2062179	1.2207746	1.2360680	0
	59°	58°	57°	56°	55°	54°	

NATURAL COSECANTS

NATURAL SECANTS							
	36°	37°	38°	39°	40°	41°	
0	1.2360680	1.2521357	1.2690182	1.2867596	1.3054073	1.3250130	60
1	1.2363293	1.2524102	1.2693067	1.2870628	1.3057261	1.3253482	59
2	1.2365909	1.2526850	1.2695955	1.2873663	1.3060451	1.3256837	58
3	1.2368526	1.2529601	1.2698845	1.2876700	1.3063644	1.3260194	57
4	1.2371146	1.2532353	1.2701737	1.2879740	1.3066839	1.3263554	56
5	1.2373768	1.2535108	1.2704632	1.2882782	1.3070038	1.3266918	55
6	1.2376393	1.2537865	1.2707529	1.2885827	1.3073239	1.3270284	54
7	1.2379019	1.2540625	1.2710429	1.2888875	1.3076442	1.3273653	53
8	1.2381647	1.2543387	1.2713331	1.2891925	1.3079649	1.3277024	52
9	1.2384278	1.2546151	1.2716235	1.2894977	1.3082858	1.3280399	51
10	1.2386911	1.2548917	1.2719142	1.2898032	1.3086069	1.3283776	50
11	1.2389546	1.2551685	1.2722052	1.2901090	1.3089284	1.3287156	49
12	1.2392183	1.2554456	1.2724963	1.2904150	1.3092501	1.3290539	48
13	1.2394823	1.2557229	1.2727877	1.2907213	1.3095720	1.3293925	47
14	1.2397464	1.2560005	1.2730794	1.2910278	1.3098943	1.3297314	46
15	1.2400108	1.2562782	1.2733712	1.2913346	1.3102168	1.3300706	45
16	1.2402754	1.2565562	1.2736634	1.2916416	1.3105396	1.3304100	44
17	1.2405402	1.2568345	1.2739557	1.2919489	1.3108626	1.3307497	43
18	1.2408052	1.2571129	1.2742484	1.2922564	1.3111860	1.3310897	42
19	1.2410704	1.2573916	1.2745412	1.2925642	1.3115095	1.3314301	41
20	1.2413359	1.2576705	1.2748343	1.2928723	1.3118334	1.3317707	40
21	1.2416016	1.2579497	1.2751276	1.2931806	1.3121575	1.3321115	39
22	1.2418675	1.2582291	1.2754212	1.2934892	1.3124820	1.3324527	38
23	1.2421336	1.2585087	1.2757151	1.2937980	1.3128066	1.3327942	37
24	1.2423999	1.2587885	1.2760091	1.2941071	1.3131316	1.3331359	36
25	1.2426665	1.2590686	1.2763034	1.2944164	1.3134568	1.3334779	35
26	1.2429333	1.2593489	1.2765980	1.2947260	1.3137823	1.3338203	34
27	1.2432003	1.2596294	1.2768928	1.2950359	1.3141081	1.3341629	33
28	1.2434675	1.2599102	1.2771878	1.2953460	1.3144341	1.3345058	32
29	1.2437349	1.2601912	1.2774831	1.2956564	1.3147604	1.3348489	31
30	1.2440026	1.2604724	1.2777787	1.2959670	1.3150870	1.3351924	30
31	1.2442704	1.2607539	1.2780744	1.2962779	1.3154139	1.3355362	29
32	1.2445385	1.2610356	1.2783705	1.2965890	1.3157410	1.3358802	28
33	1.2448069	1.2613175	1.2786667	1.2969004	1.3160684	1.3362246	27
34	1.2450754	1.2615997	1.2789632	1.2972121	1.3163961	1.3365692	26
35	1.2453442	1.2618820	1.2792600	1.2975240	1.3167240	1.3369141	25
36	1.2456131	1.2621647	1.2795570	1.2978362	1.3170523	1.3372594	24
37	1.2458823	1.2624475	1.2798543	1.2981487	1.3173808	1.3376049	23
38	1.2461518	1.2627306	1.2801518	1.2984614	1.3177096	1.3379507	22
39	1.2464214	1.2630140	1.2804495	1.2987743	1.3180386	1.3382968	21
40	1.2466913	1.2632975	1.2807475	1.2990876	1.3183680	1.3386432	20
41	1.2469614	1.2635813	1.2810457	1.2994011	1.3186976	1.3389898	19
42	1.2472317	1.2638653	1.2813442	1.2997148	1.3190274	1.3393368	18
43	1.2475022	1.2641496	1.2816430	1.3000288	1.3193576	1.3396841	17
44	1.2477730	1.2644341	1.2819419	1.3003431	1.3196881	1.3400316	16
45	1.2480440	1.2647188	1.2822412	1.3006576	1.3200188	1.3403795	15
46	1.2483152	1.2650038	1.2825407	1.3009724	1.3203498	1.3407276	14
47	1.2485866	1.2652890	1.2828404	1.3012875	1.3206810	1.3410761	13
48	1.2488583	1.2655745	1.2831404	1.3016028	1.3210126	1.3414248	12
49	1.2491302	1.2658601	1.2834406	1.3019184	1.3213444	1.3417738	11
50	1.2494023	1.2661460	1.2837411	1.3022343	1.3216765	1.3421232	10
51	1.2496746	1.2664322	1.2840418	1.3025504	1.3220089	1.3424728	9
52	1.2499471	1.2667186	1.2843428	1.3028667	1.3223416	1.3428227	8
53	1.2502199	1.2670052	1.2846440	1.3031834	1.3226745	1.3431729	7
54	1.2504929	1.2672921	1.2849455	1.3035003	1.3230078	1.3435234	6
55	1.2507661	1.2675792	1.2852472	1.3038175	1.3233413	1.3438742	5
56	1.2510396	1.2678665	1.2855492	1.3041349	1.3236750	1.3442253	4
57	1.2513133	1.2681541	1.2858514	1.3044526	1.3240091	1.3445767	3
58	1.2515872	1.2684419	1.2861539	1.3047706	1.3243435	1.3449284	2
59	1.2518613	1.2687299	1.2864566	1.3050888	1.3246781	1.3452804	1
60	1.2521357	1.2690182	1.2867596	1.3054073	1.3250130	1.3456327	0
	53°	52°	51°	50°	49°	48°	

NATURAL SECANTS

	42°	43°	44°	45°	46°	47°	
0	1.3456327	1.3673275	1.3901636	1.4142136	1.4395565	1.4662792	60
1	1.3459853	1.3676985	1.3905543	1.4146251	1.4399904	1.4667368	59
2	1.3463382	1.3680699	1.3909453	1.4150370	1.4404246	1.4671948	58
3	1.3466914	1.3684416	1.3913366	1.4154493	1.4408592	1.4676532	57
4	1.3470449	1.3688136	1.3917283	1.4158619	1.4412941	1.4681120	56
5	1.3473987	1.3691859	1.3921203	1.4162749	1.4417295	1.4685713	55
6	1.3477528	1.3695586	1.3925127	1.4166883	1.4421652	1.4690309	54
7	1.3481072	1.3699315	1.3929054	1.4171020	1.4426013	1.4694910	53
8	1.3484619	1.3703048	1.3932985	1.4175161	1.4430379	1.4699514	52
9	1.3488168	1.3706784	1.3936918	1.4179306	1.4434748	1.4704123	51
10	1.3491721	1.3710523	1.3940856	1.4183454	1.4439120	1.4708736	50
11	1.3495277	1.3714266	1.3944796	1.4187605	1.4443497	1.4713354	49
12	1.3498836	1.3718011	1.3948740	1.4191761	1.4447878	1.4717975	48
13	1.3502398	1.3721760	1.3952688	1.4195920	1.4452262	1.4722600	47
14	1.3505963	1.3725512	1.3956639	1.4200082	1.4456651	1.4727230	46
15	1.3509531	1.3729268	1.3960593	1.4204248	1.4461043	1.4731864	45
16	1.3513102	1.3733026	1.3964551	1.4208418	1.4465439	1.4736502	44
17	1.3516677	1.3736788	1.3968512	1.4212592	1.4469839	1.4741144	43
18	1.3520254	1.3740553	1.3972477	1.4216769	1.4474243	1.4745790	42
19	1.3523834	1.3744321	1.3976445	1.4220950	1.4478651	1.4750440	41
20	1.3527417	1.3748092	1.3980416	1.4225134	1.4483063	1.4755095	40
21	1.3531003	1.3751867	1.3984391	1.4229323	1.4487478	1.4759754	39
22	1.3534593	1.3755645	1.3988369	1.4233514	1.4491898	1.4764417	38
23	1.3538185	1.3759426	1.3992351	1.4237710	1.4496322	1.4769084	37
24	1.3541780	1.3763210	1.3996336	1.4241909	1.4500749	1.4773755	36
25	1.3545379	1.3766998	1.4000325	1.4246112	1.4505181	1.4778431	35
26	1.3548980	1.3770789	1.4004317	1.4250319	1.4509616	1.4783111	34
27	1.3552585	1.3774583	1.4008313	1.4254529	1.4514055	1.4787795	33
28	1.3556193	1.3778380	1.4012312	1.4258743	1.4518498	1.4792483	32
29	1.3559803	1.3782181	1.4016315	1.4262961	1.4522946	1.4797176	31
30	1.3563417	1.3785985	1.4020321	1.4267182	1.4527397	1.4801872	30
31	1.3567034	1.3789792	1.4024330	1.4271407	1.4531852	1.4806573	29
32	1.3570654	1.3793602	1.4028343	1.4275636	1.4536311	1.4811278	28
33	1.3574277	1.3797416	1.4032360	1.4279868	1.4540774	1.4815988	27
34	1.3577903	1.3801233	1.4036380	1.4284105	1.4545241	1.4820702	26
35	1.3581532	1.3805053	1.4040403	1.4288345	1.4549712	1.4825420	25
36	1.3585164	1.3808877	1.4044430	1.4292588	1.4554187	1.4830142	24
37	1.3588800	1.3812704	1.4048461	1.4296836	1.4558666	1.4834868	23
38	1.3592438	1.3816534	1.4052494	1.4301087	1.4563149	1.4839599	22
39	1.3596080	1.3820367	1.4056532	1.4305342	1.4567636	1.4844334	21
40	1.3599725	1.3824204	1.4060573	1.4309600	1.4572127	1.4849073	20
41	1.3603372	1.3828044	1.4064617	1.4313863	1.4576621	1.4853817	19
42	1.3607023	1.3831887	1.4068665	1.4318129	1.4581120	1.4858565	18
43	1.3610677	1.3835734	1.4072717	1.4322399	1.4585623	1.4863317	17
44	1.3614334	1.3839584	1.4076772	1.4326672	1.4590130	1.4868073	16
45	1.3617995	1.3843437	1.4080831	1.4330950	1.4594641	1.4872834	15
46	1.3621658	1.3847294	1.4084893	1.4335231	1.4599156	1.4877599	14
47	1.3625324	1.3851153	1.4088958	1.4339516	1.4603675	1.4882369	13
48	1.3628994	1.3855017	1.4093028	1.4343805	1.4608198	1.4887142	12
49	1.3632667	1.3858883	1.4097100	1.4348097	1.4612726	1.4891920	11
50	1.3636343	1.3862753	1.4101177	1.4352393	1.4617257	1.4896703	10
51	1.3640022	1.3866626	1.4105257	1.4356693	1.4621792	1.4901489	9
52	1.3643704	1.3870503	1.4109340	1.4360997	1.4626331	1.4906280	8
53	1.3647389	1.3874383	1.4113427	1.4365305	1.4630875	1.4911076	7
54	1.3651078	1.3878266	1.4117517	1.4369616	1.4635422	1.4915876	6
55	1.3654770	1.3882153	1.4121612	1.4373932	1.4639973	1.4920680	5
56	1.3658464	1.3886043	1.4125709	1.4378251	1.4644529	1.4925488	4
57	1.3662162	1.3889936	1.4129810	1.4382574	1.4649089	1.4930301	3
58	1.3665863	1.3893832	1.4133915	1.4386900	1.4653652	1.4935118	2
59	1.3669567	1.3897733	1.4138024	1.4391231	1.4658220	1.4939940	1
60	1.3673275	1.3901636	1.4142136	1.4395565	1.4662792	1.4944765	0
	47°	46°	45°	44°	43°	42°	

NATURAL COSECANTS

NATURAL SECANTS							
	48°	49°	50°	51°	52°	53°	
0	1.4944765	1.5242531	1.5557238	1.5890157	1.6242692	1.6616401	60
1	1.4949596	1.5247634	1.5562034	1.5895868	1.6248743	1.6622819	59
2	1.4954431	1.5252741	1.5568035	1.5901584	1.6254799	1.6629243	58
3	1.4959270	1.5257854	1.5573441	1.5907306	1.6260861	1.6635673	57
4	1.4964113	1.5262971	1.5578852	1.5913033	1.6266929	1.6642110	56
5	1.4968961	1.5268093	1.5584268	1.5918766	1.6273003	1.6648553	55
6	1.4973813	1.5273219	1.5589689	1.5924504	1.6279083	1.6655002	54
7	1.4978670	1.5278351	1.5595115	1.5930247	1.6285169	1.6661458	53
8	1.4983531	1.5283487	1.5600546	1.5935996	1.6291261	1.6667920	52
9	1.4988397	1.5288627	1.5605982	1.5941751	1.6297359	1.6674389	51
10	1.4993267	1.5293773	1.5611424	1.5947511	1.6303462	1.6680864	50
11	1.4998141	1.5298923	1.5616871	1.5953276	1.6309572	1.6687345	49
12	1.5003020	1.5304078	1.5622322	1.5959048	1.6315688	1.6693833	48
13	1.5007903	1.5309238	1.5627779	1.5964824	1.6321809	1.6700328	47
14	1.5012791	1.5314403	1.5633241	1.5970606	1.6327937	1.6706828	46
15	1.5017683	1.5319572	1.5638708	1.5976394	1.6334070	1.6713336	45
16	1.5022580	1.5324746	1.5644181	1.5982187	1.6340210	1.6719850	44
17	1.5027481	1.5329925	1.5649658	1.5987986	1.6346355	1.6726370	43
18	1.5032387	1.5335109	1.5655141	1.5993790	1.6352507	1.6732897	42
19	1.5037297	1.5340297	1.5660628	1.5999600	1.6358664	1.6739430	41
20	1.5042211	1.5345491	1.5666121	1.6005416	1.6364828	1.6745970	40
21	1.5047131	1.5350680	1.5671619	1.6011237	1.6370997	1.6752517	39
22	1.5052054	1.5355892	1.5677123	1.6017064	1.6377173	1.6759070	38
23	1.5056982	1.5361100	1.5682631	1.6022896	1.6383355	1.6765629	37
24	1.5061915	1.5366313	1.5688145	1.6028734	1.6389542	1.6772195	36
25	1.5066852	1.5371530	1.5693664	1.6034577	1.6395736	1.6778768	35
26	1.5071793	1.5376752	1.5699188	1.6040426	1.6401936	1.6785347	34
27	1.5076739	1.5381980	1.5704717	1.6046281	1.6408142	1.6791932	33
28	1.5081690	1.5387212	1.5710252	1.6052142	1.6414354	1.6798525	32
29	1.5086645	1.5392449	1.5715792	1.6058008	1.6420572	1.6805124	31
30	1.5091605	1.5397690	1.5721337	1.6063879	1.6426796	1.6811730	30
31	1.5096569	1.5402937	1.5726887	1.6069757	1.6433027	1.6818342	29
32	1.5101538	1.5408189	1.5732443	1.6075640	1.6439263	1.6824961	28
33	1.5106511	1.5413445	1.5738004	1.6081528	1.6445506	1.6831586	27
34	1.5111489	1.5418706	1.5743570	1.6087423	1.6451754	1.6838219	26
35	1.5116472	1.5423973	1.5749141	1.6093323	1.6458009	1.6844857	25
36	1.5121459	1.5429244	1.5754718	1.6099228	1.6464270	1.6851503	24
37	1.5126450	1.5434520	1.5760300	1.6105140	1.6470537	1.6858155	23
38	1.5131446	1.5439801	1.5765887	1.6111057	1.6476811	1.6864814	22
39	1.5136447	1.5445087	1.5771479	1.6116980	1.6483090	1.6871479	21
40	1.5141452	1.5450378	1.5777077	1.6122908	1.6489376	1.6878151	20
41	1.5146462	1.5455673	1.5782680	1.6128843	1.6495668	1.6884830	19
42	1.5151477	1.5460974	1.5788289	1.6134783	1.6501966	1.6891516	18
43	1.5156496	1.5466280	1.5793902	1.6140728	1.6508270	1.6898208	17
44	1.5161520	1.5471590	1.5799521	1.6146680	1.6514581	1.6904907	16
45	1.5166548	1.5476906	1.5805146	1.6152637	1.6520898	1.6911613	15
46	1.5171581	1.5482226	1.5810776	1.6158600	1.6527221	1.6918326	14
47	1.5176619	1.5487552	1.5816411	1.6164569	1.6533550	1.6925045	13
48	1.5181661	1.5492882	1.5822051	1.6170544	1.6539885	1.6931771	12
49	1.5186708	1.5498218	1.5827697	1.6176524	1.6546227	1.6938504	11
50	1.5191759	1.5503558	1.5833348	1.6182510	1.6552575	1.6945244	10
51	1.5196815	1.5508904	1.5839005	1.6188502	1.6558929	1.6951990	9
52	1.5201876	1.5514254	1.5844667	1.6194500	1.6565290	1.6958744	8
53	1.5206942	1.5519610	1.5850334	1.6200504	1.6571657	1.6965504	7
54	1.5212012	1.5524970	1.5856007	1.6206513	1.6578030	1.6972271	6
55	1.5217087	1.5530335	1.5861685	1.6212528	1.6584409	1.6979044	5
56	1.5222166	1.5535706	1.5867369	1.6218549	1.6590795	1.6985825	4
57	1.5227250	1.5541081	1.5873058	1.6224576	1.6597187	1.6992612	3
58	1.5232339	1.5546462	1.5878752	1.6230609	1.6603586	1.6999407	2
59	1.5237433	1.5551848	1.5884452	1.6236648	1.6609990	1.7006208	1
60	1.5242531	1.5557238	1.5890157	1.6242692	1.6616401	1.7013016	0
	41°	40°	39°	38°	37°	36°	
NATURAL COSECANTS							

NATURAL SECANTS

	54°	55°	56°	57°	58°	59°	
0	1.7013016	1.7434468	1.7882916	1.8360785	1.8870799	1.9416040	60
1	1.7019831	1.7441715	1.7890633	1.8369013	1.8879589	1.9425445	59
2	1.7026653	1.7448969	1.7898357	1.8377251	1.8888388	1.9434861	58
3	1.7033482	1.7456230	1.7906090	1.8385498	1.8897197	1.9444288	57
4	1.7040318	1.7463499	1.7913831	1.8393753	1.8906016	1.9453725	56
5	1.7047160	1.7470776	1.7921580	1.8402018	1.8914845	1.9463173	55
6	1.7054010	1.7478060	1.7929337	1.8410292	1.8923684	1.9472632	54
7	1.7060867	1.7485352	1.7937102	1.8418574	1.8932532	1.9482102	53
8	1.7067730	1.7492651	1.7944876	1.8426866	1.8941391	1.9491583	52
9	1.7074601	1.7499958	1.7952658	1.8435166	1.8950259	1.9501075	51
10	1.7081478	1.7507273	1.7960449	1.8443476	1.8959138	1.9510577	50
11	1.7088362	1.7514595	1.7968247	1.8451795	1.8968026	1.9520091	49
12	1.7095254	1.7521924	1.7976054	1.8460123	1.8976924	1.9529615	48
13	1.7102152	1.7529262	1.7983869	1.8468460	1.8985832	1.9539150	47
14	1.7109058	1.7536607	1.7991693	1.8476806	1.8994750	1.9548697	46
15	1.7115970	1.7543959	1.7999524	1.8485161	1.9003678	1.9558254	45
16	1.7122890	1.7551320	1.8007365	1.8493525	1.9012616	1.9567822	44
17	1.7129817	1.7558687	1.8015213	1.8501898	1.9021564	1.9577402	43
18	1.7136750	1.7566063	1.8023070	1.8510281	1.9030522	1.9586992	42
19	1.7143691	1.7573446	1.8030935	1.8518672	1.9039491	1.9596593	41
20	1.7150639	1.7580837	1.8038809	1.8527073	1.9048469	1.9606206	40
21	1.7157594	1.7588236	1.8046691	1.8535483	1.9057457	1.9615829	39
22	1.7164556	1.7595642	1.8054582	1.8543903	1.9066456	1.9625464	38
23	1.7171525	1.7603057	1.8062481	1.8552331	1.9075464	1.9635110	37
24	1.7178501	1.7610478	1.8070388	1.8560769	1.9084483	1.9644767	36
25	1.7185484	1.7617908	1.8078304	1.8569216	1.9093512	1.9654435	35
26	1.7192475	1.7625345	1.8086228	1.8577672	1.9102551	1.9664114	34
27	1.7199472	1.7632791	1.8094161	1.8586138	1.9111600	1.9673803	33
28	1.7206477	1.7640244	1.8102102	1.8594612	1.9120659	1.9683507	32
29	1.7213489	1.7647704	1.8110052	1.8603097	1.9129729	1.9693220	31
30	1.7220508	1.7655173	1.8118010	1.8611590	1.9138809	1.9702944	30
31	1.7227534	1.7662649	1.8125977	1.8620093	1.9147899	1.9712680	29
32	1.7234568	1.7670133	1.8133953	1.8628605	1.9156999	1.9722427	28
33	1.7241609	1.7677625	1.8141937	1.8637126	1.9166110	1.9732185	27
34	1.7248657	1.7685125	1.8149929	1.8645657	1.9175230	1.9741954	26
35	1.7255712	1.7692633	1.8157930	1.8654197	1.9184362	1.9751735	25
36	1.7262774	1.7700149	1.8165940	1.8662747	1.9193503	1.9761527	24
37	1.7269844	1.7707672	1.8173958	1.8671306	1.9202655	1.9771331	23
38	1.7276921	1.7715204	1.8181985	1.8679875	1.9211817	1.9781146	22
39	1.7284005	1.7722743	1.8190021	1.8688453	1.9220990	1.9790972	21
40	1.7291096	1.7730290	1.8198065	1.8697040	1.9230173	1.9800810	20
41	1.7298195	1.7737845	1.8206118	1.8705637	1.9239366	1.9810659	19
42	1.7305301	1.7745409	1.8214179	1.8714244	1.9248570	1.9820520	18
43	1.7312414	1.7752980	1.8222249	1.8722859	1.9257784	1.9830393	17
44	1.7319535	1.7760559	1.8230328	1.8731485	1.9267009	1.9840276	16
45	1.7326663	1.7768146	1.8238416	1.8740120	1.9276244	1.9850172	15
46	1.7333798	1.7775741	1.8246512	1.8748764	1.9285490	1.9860080	14
47	1.7340941	1.7783344	1.8254617	1.8757419	1.9294746	1.9869997	13
48	1.7348091	1.7790955	1.8262731	1.8766082	1.9304013	1.9879927	12
49	1.7355248	1.7798574	1.8270854	1.8774755	1.9313290	1.9889869	11
50	1.7362413	1.7806201	1.8278985	1.8783438	1.9322578	1.9899822	10
51	1.7369585	1.7813836	1.8287125	1.8792131	1.9331876	1.9909787	9
52	1.7376764	1.7821479	1.8295274	1.8800833	1.9341185	1.9919764	8
53	1.7383951	1.7829131	1.8303432	1.8809545	1.9350505	1.9929752	7
54	1.7391145	1.7836790	1.8311599	1.8818266	1.9359835	1.9939753	6
55	1.7398347	1.7844457	1.8319774	1.8826998	1.9369176	1.9949764	5
56	1.7405556	1.7852133	1.8327959	1.8835738	1.9378527	1.9959788	4
57	1.7412773	1.7859817	1.8336152	1.8844489	1.9387889	1.9969823	3
58	1.7419997	1.7867508	1.8344354	1.8853249	1.9397262	1.9979870	2
59	1.7427229	1.7875208	1.8352569	1.8862019	1.9406646	1.9989929	1
60	1.7434468	1.7882916	1.8360785	1.8870799	1.9416040	2.0000000	0
	35°	34°	33°	32°	31°	30°	

NATURAL COSECANTS

NATURAL SECANTS							
	60°	61°	62°	63°	64°	65°	
0	2.0000000	2.0626653	2.1300545	2.2026893	2.2811720	2.3662016	60
1	2.0010083	2.0637484	2.1312205	2.2039476	2.2825335	2.3676787	59
2	2.0020177	2.0648328	2.1323880	2.2052075	2.2838967	2.3691578	58
3	2.0030283	2.0659186	2.1335570	2.2064691	2.2852618	2.3706390	57
4	2.0040402	2.0670056	2.1347274	2.2077323	2.2866286	2.3721222	56
5	2.0050532	2.0680940	2.1358993	2.2089972	2.2879974	2.3736075	55
6	2.0060674	2.0691836	2.1370726	2.2102637	2.2893679	2.3750949	54
7	2.0070828	2.0702746	2.1382475	2.2115318	2.2907403	2.3765843	53
8	2.0080994	2.0713670	2.1394238	2.2128016	2.2921145	2.3780758	52
9	2.0091172	2.0724606	2.1406015	2.2140730	2.2934906	2.3795694	51
10	2.0101362	2.0735556	2.1417808	2.2153460	2.2948685	2.3810650	50
11	2.0111564	2.0746519	2.1429615	2.2166208	2.2962483	2.3825627	49
12	2.0121779	2.0757496	2.1441438	2.2178971	2.2976299	2.3840625	48
13	2.0132005	2.0768486	2.1453275	2.2191752	2.2990134	2.3855645	47
14	2.0142243	2.0779489	2.1465127	2.2204548	2.3003988	2.3870685	46
15	2.0152494	2.0790506	2.1476993	2.2217362	2.3017860	2.3885746	45
16	2.0162756	2.0801536	2.1488875	2.2230192	2.3031751	2.3900828	44
17	2.0173031	2.0812580	2.1500772	2.2243039	2.3045660	2.3915931	43
18	2.0183318	2.0823637	2.1512684	2.2255903	2.3059588	2.3931055	42
19	2.0193618	2.0834708	2.1524611	2.2268783	2.3073536	2.3946201	41
20	2.0203929	2.0845792	2.1536553	2.2281681	2.3087501	2.3961367	40
21	2.0214253	2.0856890	2.1548510	2.2294595	2.3101486	2.3976555	39
22	2.0224589	2.0868002	2.1560482	2.2307526	2.3115490	2.3991764	38
23	2.0234937	2.0879127	2.1572469	2.2320474	2.3129513	2.4006995	37
24	2.0245297	2.0890265	2.1584471	2.2333438	2.3143554	2.4022247	36
25	2.0255670	2.0901418	2.1596489	2.2346420	2.3157615	2.4037520	35
26	2.0266056	2.0912584	2.1608522	2.2359419	2.3171695	2.4052815	34
27	2.0276453	2.0923764	2.1620570	2.2372435	2.3185794	2.4068132	33
28	2.0286863	2.0934957	2.1632633	2.2385468	2.3199912	2.4083469	32
29	2.0297286	2.0946164	2.1644712	2.2398517	2.3214049	2.4098829	31
30	2.0307720	2.0957385	2.1656806	2.2411585	2.3228205	2.4114210	30
31	2.0318168	2.0968620	2.1668915	2.2424669	2.3242381	2.4129613	29
32	2.0328628	2.0979869	2.1681040	2.2437770	2.3256575	2.4145038	28
33	2.0339100	2.0991131	2.1693180	2.2450889	2.3270790	2.4160484	27
34	2.0349585	2.1002408	2.1705335	2.2464025	2.3285023	2.4175952	26
35	2.0360082	2.1013698	2.1717506	2.2477178	2.3299276	2.4191442	25
36	2.0370592	2.1025002	2.1729693	2.2490348	2.3313548	2.4206954	24
37	2.0381114	2.1036320	2.1741895	2.2503536	2.3327840	2.4222488	23
38	2.0391649	2.1047652	2.1754113	2.2516741	2.3342152	2.4238044	22
39	2.0402197	2.1058998	2.1766346	2.2529964	2.3356482	2.4253622	21
40	2.0412757	2.1070359	2.1778595	2.2543204	2.3370833	2.4269222	20
41	2.0423330	2.1081733	2.1790859	2.2556461	2.3385203	2.4284844	19
42	2.0433916	2.1093121	2.1803139	2.2569736	2.3399593	2.4300489	18
43	2.0444515	2.1104523	2.1815435	2.2583029	2.3414002	2.4316155	17
44	2.0455126	2.1115940	2.1827746	2.2596339	2.3428432	2.4331844	16
45	2.0465750	2.1127371	2.1840074	2.2609667	2.3442881	2.4347555	15
46	2.0476386	2.1138815	2.1852417	2.2623012	2.3457349	2.4363289	14
47	2.0487036	2.1150274	2.1864775	2.2636376	2.3471838	2.4379045	13
48	2.0497698	2.1161748	2.1877150	2.2649756	2.3486347	2.4394823	12
49	2.0508373	2.1173235	2.1889541	2.2663155	2.3500875	2.4410624	11
50	2.0519061	2.1184737	2.1901947	2.2676571	2.3515424	2.4426448	10
51	2.0529762	2.1196253	2.1914370	2.2690005	2.3529992	2.4442294	9
52	2.0540476	2.1207783	2.1926808	2.2703457	2.3544581	2.4458163	8
53	2.0551203	2.1219328	2.1939262	2.2716927	2.3559189	2.4474054	7
54	2.0561942	2.1230887	2.1951733	2.2730415	2.3573818	2.4489968	6
55	2.0572695	2.1242460	2.1964219	2.2743921	2.3588467	2.4505905	5
56	2.0583460	2.1254048	2.1976721	2.2757445	2.3603136	2.4521865	4
57	2.0594239	2.1265651	2.1989240	2.2770987	2.3617826	2.4537848	3
58	2.0605031	2.1277267	2.2001775	2.2784546	2.3632535	2.4553853	2
59	2.0615836	2.1288899	2.2014326	2.2798124	2.3647265	2.4569882	1
60	2.0626653	2.1300545	2.2026893	2.2811720	2.3662016	2.4585933	0
	29°	28°	27°	26°	25°	24°	
NATURAL COSECANTS							

NATURAL SECANTS

	66°	67°	68°	69°	70°	71°	
0	2.4585933	2.5593047	2.6694672	2.7904281	2.9238044	3.0715535	60
1	2.4602008	2.5610599	2.6713906	2.7925444	2.9261431	3.0741507	59
2	2.4618106	2.5628176	2.6733171	2.7946641	2.9284858	3.0767525	58
3	2.4634227	2.5645781	2.6752465	2.7967873	2.9308326	3.0793590	57
4	2.4650371	2.5663412	2.6771790	2.7989140	2.9331833	3.0819702	56
5	2.4666538	2.5681069	2.6791145	2.8010441	2.9355380	3.0845860	55
6	2.4682729	2.5698752	2.6810530	2.8031777	2.9378968	3.0872066	54
7	2.4698943	2.5716462	2.6829945	2.8053148	2.9402597	3.0898319	53
8	2.4715181	2.5734199	2.6849391	2.8074554	2.9426265	3.0924620	52
9	2.4731442	2.5751963	2.6868867	2.8095995	2.9449975	3.0950967	51
10	2.4747726	2.5769753	2.6888374	2.8117471	2.9473725	3.0977363	50
11	2.4764034	2.5787570	2.6907912	2.8138982	2.9497516	3.1003805	49
12	2.4780366	2.5805414	2.6927480	2.8160529	2.9521348	3.1030296	48
13	2.4796721	2.5823284	2.6947079	2.8182111	2.9545221	3.1056835	47
14	2.4813100	2.5841182	2.6966709	2.8203729	2.9569135	3.1083422	46
15	2.4829503	2.5859107	2.6986370	2.8225382	2.9593090	3.1110057	45
16	2.4845929	2.5877058	2.7006061	2.8247071	2.9617087	3.1136740	44
17	2.4862380	2.5895037	2.7025784	2.8268796	2.9641125	3.1163472	43
18	2.4878854	2.5913043	2.7045538	2.8290556	2.9665205	3.1190252	42
19	2.4895352	2.5931077	2.7065323	2.8312353	2.9689327	3.1217081	41
20	2.4911874	2.5949137	2.7085139	2.8334185	2.9713490	3.1243959	40
21	2.4928421	2.5967225	2.7104987	2.8356054	2.9737695	3.1270886	39
22	2.4944991	2.5985341	2.7124866	2.8377958	2.9761942	3.1297862	38
23	2.4961586	2.6003484	2.7144777	2.8399899	2.9786231	3.1324887	37
24	2.4978204	2.6021654	2.7164719	2.8421877	2.9810563	3.1351962	36
25	2.4994848	2.6039852	2.7184693	2.8443891	2.9834936	3.1379086	35
26	2.5011515	2.6058078	2.7204698	2.8465941	2.9859352	3.1406259	34
27	2.5028207	2.6076332	2.7224735	2.8488028	2.9883811	3.1433483	33
28	2.5044923	2.6094613	2.7244804	2.8510152	2.9908312	3.1460756	32
29	2.5061663	2.6112922	2.7264905	2.8532312	2.9932856	3.1488079	31
30	2.5078428	2.6131259	2.7285038	2.8554510	2.9957443	3.1515453	30
31	2.5095218	2.6149624	2.7305203	2.8576744	2.9982073	3.1542877	29
32	2.5112032	2.6168018	2.7325400	2.8599015	3.0006746	3.1570351	28
33	2.5128871	2.6186439	2.7345630	2.8621324	3.0031462	3.1597876	27
34	2.5145735	2.6204888	2.7365892	2.8643670	3.0056221	3.1625452	26
35	2.5162624	2.6223366	2.7386186	2.8666053	3.0081024	3.1653078	25
36	2.5179537	2.6241872	2.7406512	2.8688474	3.0105870	3.1680756	24
37	2.5196475	2.6260406	2.7426871	2.8710932	3.0130760	3.1708484	23
38	2.5213438	2.6278969	2.7447263	2.8733428	3.0155694	3.1736264	22
39	2.5230426	2.6297560	2.7467687	2.8755961	3.0180672	3.1764095	21
40	2.5247440	2.6316180	2.7488144	2.8778532	3.0205693	3.1791978	20
41	2.5264478	2.6334828	2.7508634	2.8801142	3.0230759	3.1819913	19
42	2.5281541	2.6353506	2.7529157	2.8823789	3.0255868	3.1847899	18
43	2.5298630	2.6372211	2.7549712	2.8846474	3.0281023	3.1875937	17
44	2.5315744	2.6390946	2.7570301	2.8869198	3.0306221	3.1904028	16
45	2.5332883	2.6409710	2.7590923	2.8891960	3.0331464	3.1932170	15
46	2.5350048	2.6428502	2.7611578	2.8914760	3.0356752	3.1960365	14
47	2.5367238	2.6447323	2.7632267	2.8937598	3.0382084	3.1988613	13
48	2.5384453	2.6466174	2.7652988	2.8960475	3.0407462	3.2016913	12
49	2.5401694	2.6485054	2.7673744	2.8983391	3.0432884	3.2045266	11
50	2.5418961	2.6503962	2.7694532	2.9006346	3.0458352	3.2073673	10
51	2.5436253	2.6522901	2.7715355	2.9029339	3.0483864	3.2102132	9
52	2.5453571	2.6541868	2.7736211	2.9052372	3.0509423	3.2130644	8
53	2.5470915	2.6560865	2.7757100	2.9075443	3.0535026	3.2159210	7
54	2.5488284	2.6579891	2.7778024	2.9098553	3.0560675	3.2187830	6
55	2.5505680	2.6598947	2.7798982	2.9121703	3.0586370	3.2216503	5
56	2.5523101	2.6618033	2.7819973	2.9144892	3.0612111	3.2245230	4
57	2.5540548	2.6637148	2.7840999	2.9168121	3.0637898	3.2274011	3
58	2.5558022	2.6656292	2.7862059	2.9191389	3.0663731	3.2302846	2
59	2.5575521	2.6675467	2.7883153	2.9214697	3.0689610	3.2331736	1
60	2.5593047	2.6694672	2.7904281	2.9238044	3.0715535	3.2360680	0
	23°	22°	21°	20°	19°	18°	

NATURAL COSECANTS

NATURAL SECANTS							
	72°	73°	74°	75°	76°	77°	
0	3.2330680	3.4203036	3.6279553	3.8637033	4.1335655	4.4454115	60
1	3.2389678	3.4235611	3.6316395	3.8679025	4.1383939	4.4510198	59
2	3.2418732	3.4268251	3.6353316	3.8721112	4.1432339	4.4566428	58
3	3.2447840	3.4300956	3.6390315	3.8763293	4.1480856	4.4622803	57
4	3.2477003	3.4333727	3.6427392	3.8805570	4.1529491	4.4679324	56
5	3.2506222	3.4366563	3.6464548	3.8847943	4.1578243	4.4735993	55
6	3.2535496	3.4399465	3.6501783	3.8890411	4.1627114	4.4792810	54
7	3.2564825	3.4432433	3.6539097	3.8932976	4.1676102	4.4849775	53
8	3.2594211	3.4465467	3.6576491	3.8975637	4.1725210	4.4906889	52
9	3.2623652	3.4498568	3.6613964	3.9018395	4.1774438	4.4964152	51
10	3.2653149	3.4531735	3.6651518	3.9061250	4.1823785	4.5021565	50
11	3.2682702	3.4564969	3.6689151	3.9104203	4.1873252	4.5079129	49
12	3.2712311	3.4598269	3.6726865	3.9147254	4.1922840	4.5136844	48
13	3.2741977	3.4631637	3.6764660	3.9190403	4.1972549	4.5194711	47
14	3.2771700	3.4665073	3.6802536	3.9233651	4.2022380	4.5252730	46
15	3.2801479	3.4698576	3.6840493	3.9276997	4.2072333	4.5310903	45
16	3.2831316	3.4732146	3.6878532	3.9320443	4.2122408	4.5369229	44
17	3.2861209	3.4765785	3.6916652	3.9363988	4.2172606	4.5427709	43
18	3.2891160	3.4799492	3.6954854	3.9407633	4.2222928	4.5486344	42
19	3.2921168	3.4833267	3.6993139	3.9451379	4.2273373	4.5545134	41
20	3.2951234	3.4867110	3.7031506	3.9495224	4.2323943	4.5604080	40
21	3.2981357	3.4901023	3.7069956	3.9539171	4.2374637	4.5663183	39
22	3.3011539	3.4935004	3.7108489	3.9583219	4.2425457	4.5722444	38
23	3.3041778	3.4969055	3.7147105	3.9627369	4.2476402	4.5781862	37
24	3.3072076	3.5003175	3.7185805	3.9671621	4.2527474	4.5841439	36
25	3.3102432	3.5037365	3.7224589	3.9715975	4.2578671	4.5901174	35
26	3.3132847	3.5071625	3.7263457	3.9760431	4.2629996	4.5961070	34
27	3.3163320	3.5105954	3.7302409	3.9804991	4.2681449	4.6021126	33
28	3.3193853	3.5140354	3.7341446	3.9849654	4.2733029	4.6081343	32
29	3.3224444	3.5174824	3.7380568	3.9894421	4.2784738	4.6141722	31
30	3.3255095	3.5209365	3.7419775	3.9939292	4.2836576	4.6202263	30
31	3.3285805	3.5243977	3.7459068	3.9984267	4.2888543	4.6262967	29
32	3.3316575	3.5278660	3.7498447	4.0029347	4.2940640	4.6323835	28
33	3.3347405	3.5313414	3.7537911	4.0074532	4.2992867	4.6384867	27
34	3.3378294	3.5348240	3.7577462	4.0119823	4.3045225	4.6446064	26
35	3.3409244	3.5383138	3.7617100	4.0165219	4.3097715	4.6507427	25
36	3.3440254	3.5418107	3.7656824	4.0210722	4.3150336	4.6568956	24
37	3.3471324	3.5453149	3.7696636	4.0256332	4.3203090	4.6630652	23
38	3.3502455	3.5488263	3.7736535	4.0302048	4.3255977	4.6692516	22
39	3.3533647	3.5523450	3.7776522	4.0347872	4.3308996	4.6754548	21
40	3.3564900	3.5558710	3.7816596	4.0393804	4.3362150	4.6816748	20
41	3.3596214	3.5594042	3.7856760	4.0439844	4.3415438	4.6879119	19
42	3.3627589	3.5629448	3.7897011	4.0485992	4.3468861	4.6941660	18
43	3.3659026	3.5664928	3.7937352	4.0532249	4.3522419	4.7004372	17
44	3.3690524	3.5700481	3.7977782	4.0578615	4.3576113	4.7067256	16
45	3.3722084	3.5736108	3.8018301	4.0625091	4.3629943	4.7130313	15
46	3.3753707	3.5771810	3.8058911	4.0671677	4.3683910	4.7193542	14
47	3.3785391	3.5807586	3.8099610	4.0718374	4.3738015	4.7256945	13
48	3.3817138	3.5843437	3.8140399	4.0765181	4.3792257	4.7320524	12
49	3.3848948	3.5879362	3.8181280	4.0812100	4.3846638	4.7384277	11
50	3.3880820	3.5915363	3.8222251	4.0859130	4.3901158	4.7448206	10
51	3.3912755	3.5951439	3.8263313	4.0906272	4.3955817	4.7512312	9
52	3.3944754	3.5987590	3.8304467	4.0953526	4.4010616	4.7576596	8
53	3.3976816	3.6023818	3.8345713	4.1000893	4.4065556	4.7641058	7
54	3.4008941	3.6060121	3.8387052	4.1048374	4.4120637	4.7705699	6
55	3.4041130	3.6096501	3.8428482	4.1095967	4.4175859	4.7770519	5
56	3.4073382	3.6132957	3.8470006	4.1143675	4.4231224	4.7835520	4
57	3.4105699	3.6169490	3.8511622	4.1191498	4.4286731	4.7900702	3
58	3.4138080	3.6206101	3.8553332	4.1239435	4.4342382	4.7966066	2
59	3.4170526	3.6242788	3.8595135	4.1287487	4.4398176	4.8031613	1
60	3.4203036	3.6279553	3.8637033	4.1335655	4.4454115	4.8097343	0
	17°	16°	15°	14°	13°	12°	
NATURAL COSECANTS							

NATURAL SECANTS

	78°	79°	80°	81°	82°	83°	
0	4.8097343	5.2408431	5.7587705	5.3924532	7.1852065	8.2055090	60
1	4.8163258	5.2486979	5.7682867	6.4042154	7.2001996	8.2249952	59
2	4.8229357	5.2565768	5.7778350	6.4160216	7.2151653	8.2445748	58
3	4.8295643	5.2644798	5.7874153	6.4278719	7.2301940	8.2642485	57
4	4.8362114	5.2724070	5.7970280	6.4397666	7.2452859	8.2840171	56
5	4.8428774	5.2803587	5.8066732	6.4517059	7.2604417	8.3038812	55
6	4.8495621	5.2883347	5.8163510	6.4636901	7.2756616	8.3238415	54
7	4.8562657	5.2963354	5.8260617	6.4757195	7.2909460	8.3438986	53
8	4.8629883	5.3043608	5.8358053	6.4877944	7.3062954	8.3640534	52
9	4.8697299	5.3124109	5.8455820	6.4999148	7.3217102	8.3843065	51
10	4.8764907	5.3204860	5.8553921	6.5120812	7.3371909	8.4046586	50
11	4.8832707	5.3285861	5.8652356	6.5242938	7.3527377	8.4251105	49
12	4.8900700	5.3367114	5.8751128	6.5365528	7.3683512	8.4456629	48
13	4.8968886	5.3448620	5.8850238	6.5488586	7.3840318	8.4663165	47
14	4.9037267	5.3530379	5.8949688	6.5612113	7.3997798	8.4870721	46
15	4.9105844	5.3612393	5.9049479	6.5736112	7.4155959	8.5079304	45
16	4.9174616	5.3694664	5.9149614	6.5860587	7.4314803	8.5288923	44
17	4.9243586	5.3777192	5.9250095	6.5985540	7.4474335	8.5499584	43
18	4.9312754	5.3859979	5.9350922	6.6110973	7.4634560	8.5711295	42
19	4.9382120	5.3943026	5.9452098	6.6236890	7.4795482	8.5924065	41
20	4.9451687	5.4026333	5.9553625	6.6363293	7.4957106	8.6137901	40
21	4.9521453	5.4109903	5.9655504	6.6490184	7.5119437	8.6352812	39
22	4.9591421	5.4193737	5.9757737	6.6617568	7.5282478	8.6568805	38
23	4.9661591	5.4277835	5.9860326	6.6745446	7.5446236	8.6785889	37
24	4.9731964	5.4362199	5.9963274	6.6873822	7.5610713	8.7004071	36
25	4.9802541	5.4446831	6.0066581	6.7002699	7.5775916	8.7223361	35
26	4.9873323	5.4531731	6.0170250	6.7132079	7.5941849	8.7443766	34
27	4.9944311	5.4616901	6.0274282	6.7261965	7.6108516	8.7665295	33
28	5.0015505	5.4702342	6.0378680	6.7392360	7.6275923	8.7887957	32
29	5.0086907	5.4788056	6.0483445	6.7523268	7.6444075	8.8111761	31
30	5.0158517	5.4874043	6.0588580	6.7654691	7.6612976	8.8336715	30
31	5.0230337	5.4960305	6.0694085	6.7786632	7.6782631	8.8562828	29
32	5.0302367	5.5046843	6.0799964	6.7919095	7.6953047	8.8790109	28
33	5.0374607	5.5133659	6.0906219	6.8052082	7.7124227	8.9018567	27
34	5.0447060	5.5220754	6.1012850	6.8185597	7.7296176	8.9248211	26
35	5.0519726	5.5308129	6.1119861	6.8319642	7.7468901	8.9479051	25
36	5.0592606	5.5395786	6.1227253	6.8454222	7.7642406	8.9711095	24
37	5.0665701	5.5483726	6.1335028	6.8589338	7.7816697	8.9944354	23
38	5.0739012	5.5571951	6.1443189	6.8724995	7.7991778	9.0178837	22
39	5.0812539	5.5660460	6.1551736	6.8861195	7.8167656	9.0414553	21
40	5.0886284	5.5749258	6.1660674	6.8997942	7.8344335	9.0651512	20
41	5.0960248	5.5838343	6.1770003	6.9135239	7.8521821	9.0889725	19
42	5.1034431	5.5927719	6.1879725	6.9273089	7.8700120	9.1129200	18
43	5.1108835	5.6017386	6.1989843	6.9411496	7.8879238	9.1369949	17
44	5.1183461	5.6107345	6.2100359	6.9550464	7.9059179	9.1611980	16
45	5.1258309	5.6197599	6.2211275	6.9689994	7.9239950	9.1855305	15
46	5.1333381	5.6288148	6.2322594	6.9830092	7.9421556	9.2099934	14
47	5.1408677	5.6378995	6.2434316	6.9970760	7.9604003	9.2345877	13
48	5.1484199	5.6470140	6.2546446	7.0112001	7.9787298	9.2593145	12
49	5.1559948	5.6561584	6.2658984	7.0253820	7.9971445	9.2841749	11
50	5.1635924	5.6653331	6.2771933	7.0396220	8.0156450	9.3091699	10
51	5.1712128	5.6745380	6.2885295	7.0539205	8.0342321	9.3343006	9
52	5.1788563	5.6837734	6.2999073	7.0682777	8.0529062	9.3595682	8
53	5.1865228	5.6930393	6.3113269	7.0826941	8.0716681	9.3849738	7
54	5.1942125	5.7023360	6.3227884	7.0971700	8.0905182	9.4105184	6
55	5.2019254	5.7116636	6.3342923	7.1117059	8.1094573	9.4362033	5
56	5.2096618	5.7210223	6.3458386	7.1263019	8.1284860	9.4620296	4
57	5.2174216	5.7304121	6.3574276	7.1409587	8.1476048	9.4879984	3
58	5.2252050	5.7398333	6.3690595	7.1556764	8.1668145	9.5141110	2
59	5.2330121	5.7492861	6.3807347	7.1704556	8.1861157	9.5403686	1
60	5.2408431	5.7587705	6.3924532	7.1852965	8.2055090	9.5667722	0
	11°	10°	9°	8°	7°	6°	

NATURAL COSECANTS

COMPARISON OF TABLES XXIX AND XXIXA

Definitions

The versine $= 1 - \cosine$.

The exsecant $= \secant - 1$, or $\secant = \text{exsecant} + 1$

Table XXIX gives, in addition to the versine, values of the exsecant.

Table XXIXA—NATURAL SECANTS AND COSECANTS is obtained from the equation above, viz., $\secant = \text{exsecant} + 1$. Use of this table avoids adding 1 to each quantity in the exsecant part of Table XXIX.

Note. For angles beyond 90° the following explanation will aid in use of Tables XXVI and XXIX.

VERSINE FOR ANGLES BEYOND 90 DEGREES

In Tables XXVI and XXIX the values of log versine and nat versine are extended to 90° .

When the given angle A is greater than 90° , make the following substitution:

$$\log \text{vers } A = \log 2 \sin^2 - \frac{1}{2}A,$$

or

$$\text{vers } A = 1 + \sin(A - 90^\circ).$$

Whatever be the value of A , vers A is always positive.

The exsecant of the supplement of an angle is the same as exsecant of the angle itself but with a change of sign; thus,

$$\text{exsec } A = - \text{exsec } (180^\circ - A).$$

Depth d	Base 12	Base 14	Base 16	Base 18	Base 22	Base 24	Base 26	Base 28
1	45	53	60	68	82	90	97	105
2	93	107	122	137	167	181	196	211
3	142	163	186	208	253	275	297	319
4	193	222	252	281	341	370	400	430
5	245	282	319	356	431	468	505	542
6	300	344	389	433	522	567	611	656
7	356	408	460	512	616	668	719	771
8	415	474	533	593	711	770	830	889
9	475	542	608	675	808	875	942	1008
10	537	611	685	759	907	981	1056	1130
11	601	682	764	845	1008	1090	1171	1253
12	667	756	844	933	1111	1200	1289	1378
13	734	831	926	1023	1216	1312	1408	1505
14	804	907	1010	1115	1322	1426	1530	1633
15	875	986	1096	1208	1431	1542	1653	1764
16	948	1067	1184	1304	1541	1659	1778	1896
17	1023	1149	1274	1401	1653	1779	1905	2031
18	1100	1233	1366	1500	1767	1900	2033	2167
19	1179	1319	1460	1601	1882	2023	2164	2305
20	1259	1407	1555	1704	2000	2148	2296	2444
21	1342	1497	1653	1808	2119	2275	2431	2586
22	1426	1589	1752	1915	2241	2404	2567	2730
23	1512	1682	1853	2023	2364	2534	2705	2875
24	1600	1778	1955	2133	2489	2667	2844	3022
25	1690	1875	2060	2245	2616	2801	2986	3171
26	1781	1974	2166	2359	2744	2927	3130	3322
27	1875	2075	2274	2475	2875	3075	3275	3475
28	1970	2178	2384	2593	3007	3215	3422	3630
29	2068	2282	2496	2712	3142	3356	3571	3786
30	2167	2389	2610	2833	3278	3500	3722	3944
31	2268	2497	2726	2956	3416	3645	3875	4105
32	2370	2607	2844	3081	3556	3793	4030	4267
33	2475	2719	2964	3208	3697	3942	4186	4431
34	2581	2833	3085	3337	3841	4093	4344	4596
35	2690	2949	3208	3468	3986	4245	4505	4764
36	2800	3067	3333	3600	4133	4400	4667	4933
37	2912	3186	3460	3734	4282	4556	4831	5105
38	3026	3307	3589	3870	4433	4715	4996	5278
39	3142	3431	3719	4008	4586	4875	5164	5453
40	3259	3556	3852	4148	4741	5037	5333	5630
41	3379	3682	3986	4290	4897	5201	5505	5808
42	3500	3811	4122	4433	5056	5367	5678	5989
43	3623	3942	4260	4579	5216	5534	5853	6171
44	3748	4074	4400	4726	5378	5704	6030	6356
45	3875	4208	4541	4875	5542	5875	6208	6542
46	4004	4344	4684	5026	5707	6048	6389	6730
47	4134	4482	4830	5179	5875	6223	6571	6919
48	4267	4622	4978	5333	6044	6400	6756	7111
49	4401	4764	5127	5490	6216	6579	6942	7305
50	4537	4907	5278	5648	6389	6759	7130	7500
51	4675	5053	5430	5808	6564	6942	7319	7697
52	4815	5200	5584	5970	6741	7126	7511	7896
53	4956	5349	5741	6134	6919	7312	7705	8097
54	5100	5500	5900	6300	7100	7500	7900	8300
55	5245	5653	6060	6468	7282	7690	8097	8505
56	5393	5807	6222	6637	7467	7881	8296	8711
57	5542	5964	6386	6808	7653	8075	8497	8919
58	5693	6122	6552	6981	7841	8270	8700	9130
59	5845	6282	6719	7156	8031	8468	8905	9342
60	6000	6444	6889	7333	8222	8667	9111	9556

TABLE XXX.—CU.YDS. PER 100 FT. SLOPES $\frac{1}{2} : 1$ 275

Depth d	Base 12	Base 14	Base 16	Base 18	Base 22	Base 24	Base 26	Base 28
1	46	54	61	69	83	91	98	106
2	96	111	126	141	170	185	200	215
3	150	172	194	217	261	283	306	328
4	207	237	267	296	356	385	415	444
5	269	306	343	380	454	491	528	565
6	333	378	422	467	556	600	644	689
7	402	454	506	557	661	713	765	817
8	474	533	593	652	770	830	889	948
9	550	617	683	750	883	950	1017	1083
10	630	704	778	852	1000	1074	1148	1222
11	713	794	876	957	1120	1202	1283	1365
12	800	889	978	1067	1244	1333	1422	1511
13	891	987	1083	1180	1372	1469	1565	1661
14	985	1089	1193	1296	1504	1607	1711	1815
15	1083	1194	1306	1417	1639	1750	1861	1972
16	1185	1304	1422	1541	1779	1896	2015	2133
17	1291	1417	1543	1669	1920	2046	2172	2298
18	1400	1533	1667	1800	2067	2200	2333	2467
19	1513	1654	1794	1935	2217	2357	2498	2639
20	1630	1778	1926	2074	2370	2519	2667	2815
21	1750	1906	2061	2217	2528	2683	2839	2994
22	1874	2037	2200	2363	2689	2852	3015	3178
23	2002	2172	2343	2513	2854	3024	3194	3365
24	2133	2311	2489	2667	3022	3200	3378	3556
25	2269	2454	2639	2824	3194	3380	3565	3750
26	2407	2600	2793	2985	3370	3563	3756	3948
27	2550	2750	2950	3150	3550	3750	3950	4151
28	2696	2904	3111	3319	3733	3941	4148	4356
29	2846	3061	3276	3491	3920	4135	4350	4565
30	3000	3222	3444	3667	4111	4333	4556	4778
31	3157	3387	3617	3846	4306	4535	4765	4994
32	3319	3556	3793	4030	4504	4741	4978	5215
33	3483	3728	3972	4217	4706	4950	5194	5439
34	3652	3904	4156	4407	4911	5163	5415	5667
35	3824	4083	4343	4602	5120	5380	5639	5898
36	4000	4267	4533	4800	5333	5600	5867	6133
37	4180	4454	4728	5002	5550	5824	6098	6372
38	4363	4644	4926	5207	5770	6052	6333	6615
39	4550	4839	5128	5417	5994	6283	6572	6861
40	4741	5037	5333	5630	6222	6519	6815	7111
41	4935	5239	5543	5846	6454	6757	7061	7365
42	5133	5444	5756	6067	6689	7000	7311	7623
43	5335	5654	5972	6291	6928	7246	7565	7883
44	5541	5867	6193	6519	7170	7496	7822	8148
45	5750	6083	6417	6750	7417	7750	8083	8417
46	5963	6304	6644	6985	7667	8007	8348	8689
47	6180	6528	6876	7224	7920	8269	8617	8965
48	6400	6756	7111	7467	8178	8533	8889	9244
49	6624	6987	7350	7713	8439	8802	9165	9528
50	6852	7222	7593	7963	8704	9074	9444	9815
51	7083	7461	7839	8217	8973	9350	9728	10106
52	7319	7704	8089	8474	9244	9630	10015	10400
53	7557	7950	8343	8735	9520	9913	10306	10698
54	7800	8200	8600	9000	9800	10200	10600	11000
55	8046	8454	8861	9269	10083	10491	10898	11306
56	8296	8711	9126	9541	10370	10785	11200	11615
57	8550	8972	9394	9817	10661	11083	11506	11928
58	8807	9237	9667	10096	10956	11385	11815	12244
59	9069	9506	9943	10380	11254	11691	12128	12565
60	9333	9778	10222	10667	11556	12000	12444	12889

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	48	56	63	70	78	107	115	122
2	104	119	133	148	163	222	237	252
3	167	189	211	233	256	344	367	389
4	237	267	296	326	356	474	504	533
5	315	352	389	426	463	611	648	685
6	400	444	489	533	578	756	800	844
7	493	544	596	648	700	907	959	1011
8	593	652	711	770	830	1067	1126	1185
9	700	767	833	900	967	1233	1300	1367
10	815	889	963	1037	1111	1407	1481	1556
11	937	1019	1100	1181	1263	1589	1670	1752
12	1067	1156	1244	1333	1422	1778	1867	1956
13	1204	1300	1396	1493	1589	1974	2070	2167
14	1348	1452	1556	1659	1763	2178	2281	2385
15	1500	1611	1722	1833	1944	2389	2500	2611
16	1659	1778	1896	2015	2133	2607	2726	2844
17	1826	1952	2078	2204	2330	2833	2959	3085
18	2000	2133	2267	2400	2533	3067	3200	3333
19	2181	2322	2463	2604	2744	3307	3448	3589
20	2370	2519	2667	2815	2963	3556	3704	3852
21	2567	2722	2878	3033	3189	3811	3967	4122
22	2770	2933	3096	3259	3422	4074	4237	4400
23	2981	3152	3322	3493	3663	4344	4515	4685
24	3200	3378	3556	3733	3911	4622	4800	4978
25	3426	3611	3796	3981	4167	4907	5093	5278
26	3659	3852	4044	4237	4430	5200	5393	5585
27	3900	4100	4300	4500	4700	5500	5700	5900
28	4148	4356	4563	4770	4978	5807	6015	6222
29	4404	4619	4833	5048	5263	6122	6337	6552
30	4667	4889	5111	5333	5556	6444	6667	6889
31	4937	5167	5396	5626	5856	6774	7004	7233
32	5215	5452	5689	5926	6163	7111	7348	7585
33	5500	5744	5989	6233	6478	7456	7700	7944
34	5793	6044	6296	6548	6800	7807	8059	8311
35	6093	6352	6611	6870	7130	8167	8426	8685
36	6400	6667	6933	7200	7467	8533	8800	9067
37	6715	6989	7263	7537	7811	8907	9181	9456
38	7037	7319	7600	7881	8163	9289	9570	9852
39	7367	7656	7944	8233	8522	9678	9967	10256
40	7704	8000	8296	8593	8889	10074	10370	10667
41	8048	8352	8656	8959	9263	10478	10781	11085
42	8400	8711	9022	9333	9644	10889	11200	11511
43	8759	9078	9396	9715	10033	11307	11626	11944
44	9126	9452	9778	10104	10430	11733	12059	12385
45	9500	9833	10167	10500	10833	12167	12500	12833
46	9881	10222	10563	10904	11244	12607	12948	13289
47	10270	10619	10967	11315	11663	13056	13404	13752
48	10667	11022	11378	11733	12089	13511	13867	14222
49	11070	11433	11796	12159	12522	13974	14337	14700
50	11481	11852	12222	12593	12963	14444	14815	15185
51	11900	12278	12656	13033	13411	14922	15300	15678
52	12326	12711	13096	13481	13867	15407	15793	16178
53	12759	13152	13544	13937	14330	15900	16293	16685
54	13200	13600	14000	14400	14800	16400	16800	17200
55	13648	14056	14463	14870	15278	16907	17315	17722
56	14104	14519	14933	15348	15763	17422	17837	18252
57	14567	14989	15411	15833	16256	17944	18367	18789
58	15037	15467	15896	16326	16756	18474	18904	19333
59	15515	15952	16389	16826	17263	19011	19448	19885
60	16000	16444	16889	17333	17778	19556	20000	20444

TABLE XXX.—CU.YDS. PER 100 FT. SLOPES 1¼ : 1 277

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	49	56	64	71	79	108	116	123
2	107	122	137	152	167	226	241	256
3	175	197	219	242	264	353	375	397
4	252	281	311	341	370	489	519	548
5	338	375	412	449	486	634	671	708
6	433	478	522	567	611	789	833	878
7	538	590	642	694	745	953	1005	1056
8	652	711	770	830	889	1126	1185	1244
9	775	842	908	975	1042	1308	1375	1442
10	907	981	1056	1130	1204	1500	1574	1648
11	1049	1131	1212	1294	1375	1701	1782	1864
12	1200	1289	1378	1467	1556	1911	2000	2089
13	1360	1456	1553	1649	1745	2131	2227	2323
14	1530	1633	1737	1841	1944	2359	2463	2567
15	1708	1819	1931	2042	2153	2597	2708	2819
16	1896	2015	2133	2252	2370	2844	2963	3081
17	2094	2219	2345	2471	2597	3101	3227	3353
18	2300	2433	2567	2700	2833	3367	3500	3633
19	2516	2656	2797	2938	3079	3642	3782	3923
20	2741	2889	3037	3185	3333	3926	4074	4222
21	2975	3131	3286	3442	3597	4220	4375	4531
22	3219	3381	3544	3707	3870	4522	4685	4848
23	3471	3642	3812	3982	4153	4834	5005	5175
24	3733	3911	4089	4267	4444	5156	5333	5511
25	4005	4190	4375	4560	4745	5486	5671	5856
26	4285	4478	4670	4863	5056	5826	6019	6211
27	4575	4775	4975	5175	5375	6175	6375	6575
28	4874	5081	5289	5496	5704	6533	6741	6948
29	5182	5397	5612	5827	6042	6901	7116	7331
30	5500	5722	5944	6167	6389	7278	7500	7722
31	5827	6056	6286	6516	6745	7664	7894	8123
32	6163	6400	6637	6874	7111	8059	8296	8533
33	6508	6753	6997	7242	7486	8464	8708	8953
34	6863	7115	7367	7619	7870	8878	9130	9381
35	7227	7486	7745	8005	8264	9301	9560	9819
36	7600	7867	8133	8400	8667	9733	10000	10267
37	7982	8256	8531	8805	9079	10175	10449	10723
38	8374	8656	8937	9219	9500	10626	10907	11189
39	8775	9064	9353	9642	9931	11086	11375	11664
40	9185	9481	9778	10074	10370	11556	11852	12148
41	9605	9908	10212	10516	10819	12034	12338	12642
42	10033	10344	10656	10967	11278	12522	12833	13144
43	10471	10790	11108	11427	11745	13020	13338	13656
44	10919	11244	11570	11896	12222	13526	13852	14178
45	11375	11708	12042	12375	12708	14042	14375	14708
46	11841	12181	12522	12863	13204	14567	14907	15248
47	12316	12664	13012	13360	13708	15101	15449	15797
48	12800	13156	13511	13867	14222	15644	16000	16356
49	13294	13656	14019	14382	14745	16197	16560	16923
50	13796	14167	14537	14907	15278	16759	17130	17500
51	14308	14686	15064	15442	15819	17331	17708	18086
52	14830	15215	15600	15985	16370	17911	18296	18681
53	15360	15753	16145	16538	16931	18501	18894	19286
54	15900	16300	16700	17100	17500	19100	19500	19900
55	16449	16856	17264	17671	18079	19708	20116	20523
56	17007	17422	17837	18252	18667	20326	20741	21156
57	17575	17997	18419	18842	19264	20953	21375	21797
58	18152	18581	19011	19441	19870	21589	22019	22448
59	18738	19175	19612	20049	20486	22234	22671	23108
60	19333	19778	20222	20667	21111	22889	23333	23778

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	50	57	65	72	80	109	117	124
2	111	126	141	156	170	230	244	259
3	183	206	228	250	272	361	383	406
4	267	296	326	356	385	504	533	563
5	361	398	435	472	509	657	694	731
6	467	511	556	600	644	822	867	911
7	583	665	687	739	791	998	1050	1102
8	711	770	830	889	948	1185	1244	1304
9	850	917	983	1050	1116	1383	1450	1517
10	1000	1074	1148	1222	1296	1593	1667	1741
11	1161	1243	1324	1406	1487	1813	1894	1976
12	1333	1422	1511	1600	1689	2044	2133	2222
13	1517	1613	1709	1806	1902	2287	2383	2480
14	1711	1815	1919	2022	2126	2541	2644	2748
15	1917	2028	2139	2250	2361	2806	2917	3028
16	2133	2252	2370	2489	2607	3081	3200	3319
17	2361	2487	2613	2739	2865	3369	3494	3620
18	2600	2733	2867	3000	3133	3667	3800	3933
19	2850	2991	3131	3272	3413	3976	4117	4257
20	3111	3259	3407	3556	3704	4296	4444	4592
21	3383	3539	3694	3850	4005	4628	4783	4939
22	3667	3830	3993	4156	4318	4970	5133	5296
23	3961	4131	4302	4472	4642	5324	5494	5665
24	4267	4444	4622	4800	4978	5689	5867	6044
25	4583	4769	4954	5139	5324	6065	6250	6435
26	4911	5104	5296	5489	5681	6452	6644	6837
27	5250	5450	5650	5850	6050	6850	7050	7250
28	5600	5807	6015	6222	6430	7259	7467	7674
29	5961	6176	6391	6606	6820	7680	7894	8109
30	6333	6556	6778	7000	7222	8111	8333	8555
31	6717	6946	7176	7406	7635	8554	8783	9013
32	7111	7348	7585	7822	8059	9007	9244	9482
33	7517	7761	8006	8250	8494	9472	9717	9962
34	7933	8185	8437	8689	8941	9948	10200	10452
35	8361	8620	8880	9139	9398	10435	10694	10954
36	8800	9067	9333	9600	9867	10933	11200	11467
37	9250	9524	9798	10072	10346	11443	11717	11991
38	9711	9993	10274	10556	10837	11963	12244	12526
39	10183	10472	10761	11050	11339	12494	12783	13072
40	10667	10963	11259	11556	11852	13037	13333	13630
41	11161	11465	11769	12072	12376	13591	13894	14198
42	11667	11978	12289	12600	12911	14156	14467	14778
43	12183	12502	12820	13139	13457	14731	15050	15369
44	12711	13037	13363	13689	14015	15319	15644	15970
45	13250	13583	13917	14250	14583	15917	16250	16583
46	13800	14141	14481	14822	15163	16526	16867	17207
47	14361	14709	15057	15406	15754	17146	17494	17843
48	14933	15289	15644	16000	16356	17778	18133	18489
49	15517	15880	16243	16606	16968	18420	18783	19146
50	16111	16481	16852	17222	17592	19074	19444	19815
51	16717	17094	17472	17850	18228	19739	20117	20494
52	17333	17719	18104	18489	18874	20415	20800	21185
53	17961	18354	18746	19139	19531	21102	21494	21887
54	18600	19000	19400	19800	20200	21800	22200	22600
55	19250	19657	20065	20472	20880	22509	22917	23324
56	19911	20326	20741	21156	21570	23230	23644	24059
57	20583	21006	21428	21850	22272	23961	24383	24805
58	21267	21696	22126	22556	22985	24704	25133	25563
59	21961	22398	22835	23272	23709	25457	25894	26332
60	22667	23111	23556	24000	24444	26222	26667	27111

TABLE XXX.—CU.YDS. PER 100 FT. SLOPES 2:1 279

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 23	Base 30	Base 32
1	52	59	67	74	81	111	119	126
2	119	133	143	163	178	237	252	267
3	200	222	244	267	289	378	400	422
4	296	326	356	385	415	533	563	593
5	407	444	481	519	556	704	741	778
6	533	578	622	667	711	889	933	978
7	674	726	778	830	881	1089	1141	1193
8	830	889	943	1007	1067	1304	1363	1422
9	1000	1067	1133	1200	1267	1533	1600	1667
10	1185	1259	1333	1407	1481	1778	1852	1926
11	1385	1467	1548	1630	1711	2037	2119	2200
12	1600	1689	1778	1867	1956	2311	2400	2489
13	1830	1926	2022	2119	2215	2600	2696	2793
14	2074	2178	2281	2385	2489	2904	3007	3111
15	2333	2444	2556	2667	2778	3222	3333	3444
16	2607	2726	2844	2963	3081	3556	3674	3793
17	2896	3022	3148	3274	3400	3904	4030	4156
18	3200	3333	3467	3600	3733	4267	4400	4533
19	3519	3659	3800	3941	4081	4644	4785	4926
20	3852	4000	4148	4296	4444	5037	5185	5333
21	4200	4356	4511	4667	4822	5444	5600	5756
22	4563	4730	4889	5052	5215	5867	6030	6193
23	4941	5111	5281	5452	5622	6304	6474	6644
24	5333	5511	5689	5867	6044	6756	6933	7111
25	5741	5926	6111	6296	6481	7222	7407	7593
26	6163	6356	6548	6741	6933	7704	7896	8089
27	6600	6800	7000	7200	7400	8200	8400	8600
28	7052	7259	7467	7674	7881	8711	8919	9126
29	7519	7733	7948	8163	8378	9237	9452	9667
30	8000	8222	8444	8667	8889	9778	10000	10222
31	8496	8726	8956	9185	9415	10333	10563	10793
32	9007	9244	9481	9719	9956	10904	11141	11378
33	9533	9778	10022	10267	10511	11489	11733	11978
34	10074	10326	10578	10830	11081	12089	12341	12593
35	10630	10889	11148	11407	11667	12704	12963	13222
36	11200	11467	11733	12000	12267	13333	13600	13867
37	11785	12059	12333	12607	12881	13978	14252	14526
38	12385	12667	12948	13230	13511	14637	14919	15200
39	13000	13289	13578	13867	14156	15311	15600	15889
40	13630	13926	14222	14519	14815	16000	16296	16593
41	14274	14578	14881	15185	15489	16704	17007	17311
42	14933	15244	15556	15867	16178	17422	17733	18044
43	15607	15926	16224	16533	16831	18156	18474	18793
44	16296	16622	16948	17274	17600	18904	19230	19556
45	17000	17333	17667	18000	18333	19667	20000	20333
46	17719	18059	18400	18741	19081	20444	20785	21126
47	18452	18800	19148	19496	19844	21237	21585	21933
48	19200	19556	19911	20267	20622	22044	22400	22756
49	19963	20326	20689	21052	21415	22867	23230	23593
50	20741	20711	21481	21852	22222	23704	24074	24444
51	21533	21911	22289	22667	23044	24556	24933	25311
52	22341	22726	23111	23496	23881	25422	25807	26193
53	23163	23556	23948	24341	24733	26304	26696	27089
54	24000	24400	24800	25200	25600	27200	27600	28000
55	24852	25259	25667	26074	26481	28111	28519	28926
56	25719	26133	26548	26963	27378	29037	29452	29867
57	26600	27022	27444	27867	28289	29978	30400	30822
58	27496	27926	28356	28785	29215	30933	31363	31793
59	28407	28844	29281	29719	30156	31904	32341	32778
60	29333	29778	30222	30667	31111	32889	33333	33778

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	56	63	70	78	85	115	122	130
2	133	148	163	178	193	252	267	281
3	233	256	278	300	322	411	433	456
4	356	385	415	444	474	593	622	652
5	500	537	574	611	648	796	833	870
6	667	711	756	800	844	1022	1067	1111
7	856	907	959	1011	1063	1270	1322	1374
8	1067	1126	1185	1244	1304	1541	1600	1659
9	1300	1367	1433	1500	1567	1833	1900	1967
10	1556	1630	1704	1778	1852	2148	2222	2296
11	1833	1915	1996	2078	2159	2485	2567	2648
12	2133	2222	2311	2400	2489	2844	2933	3022
13	2456	2552	2648	2744	2841	3226	3322	3419
14	2800	2904	3007	3111	3215	3630	3733	3837
15	3167	3278	3389	3500	3611	4056	4167	4278
16	3556	3674	3793	3911	4030	4504	4622	4741
17	3967	4093	4219	4344	4470	4974	5100	5226
18	4400	4533	4667	4800	4933	5467	5600	5733
19	4856	4996	5137	5278	5419	5981	6122	6263
20	5333	5481	5630	5778	5926	6519	6667	6815
21	5833	5989	6144	6300	6456	7078	7233	7389
22	6356	6519	6681	6844	7007	7659	7822	7985
23	6900	7070	7241	7411	7581	8263	8433	8504
24	7467	7644	7822	8000	8178	8889	9067	9144
25	8056	8241	8426	8611	8796	9537	9722	9807
26	8667	8859	9052	9244	9437	10207	10400	10593
27	9300	9500	9700	9900	10100	10900	11100	11300
28	9956	10163	10370	10578	10785	11615	11822	12030
29	10633	10848	11063	11278	11493	12352	12567	12781
30	11333	11556	11778	12000	12222	13111	13333	13556
31	12056	12285	12515	12744	12974	13893	14122	14352
32	12800	13037	13274	13511	13748	14696	14933	15170
33	13567	13811	14056	14300	14544	15522	15767	16011
34	14356	14607	14859	15111	15363	16370	16622	16874
35	15167	15426	15685	15944	16204	17241	17500	17759
36	16000	16267	16533	16800	17067	18133	18400	18667
37	16856	17130	17404	17678	17952	19048	19322	19596
38	17733	18015	18296	18578	18859	19985	20267	20548
39	18633	18922	19211	19500	19789	20944	21233	21522
40	19556	19852	20148	20444	20741	21926	22222	22516
41	20500	20804	21107	21411	21715	22930	23233	23537
42	21467	21778	22089	22400	22711	23956	24267	24578
43	22456	22774	23093	23411	23730	25004	25322	25641
44	23467	23793	24119	24444	24770	26074	26400	26726
45	24500	24833	25167	25500	25833	27167	27500	27833
46	25556	25896	26237	26578	26919	28281	28622	28963
47	26633	26981	27330	27678	28026	29419	29767	30115
48	27733	28089	28444	28800	29156	30578	30933	31289
49	28856	29219	29581	29944	30307	31759	32122	32485
50	30000	30370	30741	31111	31481	32963	33333	33704
51	31167	31544	31922	32300	32678	34189	34567	34944
52	32356	32741	33126	33511	33896	35437	35822	36207
53	33567	33959	34352	34744	35137	36707	37100	37493
54	34800	35200	35600	36000	36400	38000	38400	38800
55	36056	36463	36870	37278	37685	39315	39722	40130
56	37333	37748	38163	38578	38993	40652	41067	41481
57	38633	39056	39478	39900	40322	42011	42433	42856
58	39956	40385	40815	41244	41674	43393	43822	44252
59	41300	41737	42174	42611	43048	44796	45233	45670
60	42667	43111	43556	44000	44444	46222	46667	47111

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
0.1	.093	.185	.278	.370	.463	.566	.648	.741	.833
.2	.185	.370	.556	.741	.926	1.111	1.296	1.481	1.667
.3	.278	.556	.833	1.111	1.389	1.667	1.944	2.222	2.500
.4	.370	.741	1.111	1.481	1.852	2.222	2.593	2.963	3.333
.5	.463	.926	1.389	1.852	2.315	2.778	3.241	3.704	4.167
.6	.556	1.111	1.667	2.222	2.778	3.333	3.889	4.444	5.000
.7	.648	1.296	1.944	2.593	3.241	3.889	4.537	5.185	5.833
.8	.741	1.481	2.222	2.963	3.704	4.444	5.185	5.926	6.667
.9	.833	1.667	2.500	3.333	4.167	5.000	5.833	6.667	7.500
1.0	.926	1.852	2.778	3.704	4.630	5.556	6.481	7.407	8.333
.1	1.019	2.037	3.056	4.074	5.093	6.111	7.130	8.148	9.167
.2	1.111	2.222	3.333	4.444	5.556	6.667	7.778	8.889	10.000
.3	1.204	2.407	3.611	4.815	6.019	7.222	8.426	9.630	10.833
.4	1.296	2.593	3.889	5.185	6.481	7.778	9.074	10.370	11.667
.5	1.389	2.778	4.167	5.556	6.944	8.333	9.722	11.111	12.500
.6	1.481	2.963	4.444	5.926	7.407	8.889	10.370	11.852	13.333
.7	1.574	3.148	4.722	6.296	7.870	9.444	11.019	12.593	14.167
.8	1.667	3.333	5.000	6.667	8.333	10.000	11.667	13.333	15.000
.9	1.759	3.519	5.278	7.037	8.796	10.556	12.315	14.074	15.833
2.0	1.852	3.704	5.556	7.407	9.259	11.111	12.963	14.815	16.667
.1	1.944	3.889	5.833	7.778	9.722	11.667	13.611	15.556	17.500
.2	2.037	4.074	6.111	8.148	10.185	12.222	14.259	16.296	18.333
.3	2.130	4.259	6.389	8.519	10.648	12.778	14.907	17.037	19.167
.4	2.222	4.444	6.667	8.889	11.111	13.333	15.556	17.778	20.000
.5	2.315	4.630	6.944	9.259	11.574	13.889	16.204	18.519	20.833
.6	2.407	4.815	7.222	9.630	12.037	14.444	16.852	19.259	21.667
.7	2.500	5.000	7.500	10.000	12.500	15.000	17.500	20.000	22.500
.8	2.593	5.185	7.778	10.370	12.963	15.556	18.148	20.741	23.333
.9	2.685	5.370	8.056	10.741	13.426	16.111	18.796	21.481	24.167
3.0	2.778	5.556	8.333	11.111	13.889	16.667	19.444	22.222	25.000
.1	2.870	5.741	8.611	11.481	14.352	17.222	20.093	22.963	25.833
.2	2.963	5.926	8.889	11.852	14.815	17.778	20.741	23.704	26.667
.3	3.056	6.111	9.167	12.222	15.278	18.333	21.389	24.444	27.500
.4	3.148	6.296	9.444	12.593	15.741	18.889	22.037	25.185	28.333
.5	3.241	6.481	9.722	12.963	16.204	19.444	22.685	25.926	29.167
.6	3.333	6.667	10.000	13.333	16.667	20.000	23.333	26.667	30.000
.7	3.426	6.852	10.278	13.704	17.130	20.556	23.981	27.407	30.833
.8	3.519	7.037	10.556	14.074	17.593	21.111	24.630	28.148	31.667
.9	3.611	7.222	10.833	14.444	18.056	21.667	25.278	28.889	32.500
4.0	3.704	7.407	11.111	14.815	18.519	22.222	25.926	29.630	33.333
.1	3.796	7.593	11.389	15.185	18.981	22.778	26.574	30.370	34.167
.2	3.889	7.778	11.667	15.556	19.444	23.333	27.222	31.111	35.000
.3	3.981	7.963	11.944	15.926	19.907	23.889	27.870	31.852	35.833
.4	4.074	8.148	12.222	16.296	20.370	24.444	28.519	32.593	36.667
.5	4.167	8.333	12.500	16.667	20.833	25.000	29.167	33.333	37.500
.6	4.259	8.519	12.778	17.037	21.296	25.556	29.815	34.074	38.333
.7	4.352	8.704	13.056	17.407	21.759	26.111	30.463	34.815	39.167
.8	4.444	8.889	13.333	17.778	22.222	26.667	31.111	35.556	40.000
.9	4.537	9.074	13.611	18.148	22.685	27.222	31.759	36.296	40.833
5.0	4.630	9.259	13.889	18.519	23.148	27.778	32.407	37.037	41.667
.1	4.722	9.444	14.167	18.889	23.611	28.333	33.056	37.778	42.500
.2	4.815	9.630	14.444	19.259	24.074	28.889	33.704	38.519	43.333
.3	4.907	9.815	14.722	19.630	24.537	29.444	34.352	39.259	44.167
.4	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000
.5	5.093	10.185	15.278	20.370	25.463	30.556	35.648	40.741	45.833
.6	5.185	10.370	15.556	20.741	25.926	31.111	36.296	41.481	46.667
.7	5.278	10.556	15.833	21.111	26.389	31.667	36.944	42.222	47.500
.8	5.370	10.741	16.111	21.481	26.852	32.222	37.593	42.963	48.333
.9	5.463	10.926	16.389	21.852	27.315	32.778	38.241	43.704	49.167
6.0	5.556	11.111	16.667	22.222	27.778	33.333	38.889	44.444	50.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
6.1	5.648	11.296	16.944	22.593	28.241	33.889	39.537	45.185	50.833
.2	5.741	11.481	17.222	22.963	28.704	34.444	40.185	45.926	51.667
.3	5.833	11.667	17.500	23.333	29.167	35.000	40.833	46.667	52.500
.4	5.926	11.852	17.778	23.704	29.630	35.556	41.481	47.407	53.333
.5	6.019	12.037	18.056	24.074	30.093	36.111	42.130	48.148	54.167
.6	6.111	12.222	18.333	24.444	30.556	36.667	42.778	48.889	55.000
.7	6.204	12.407	18.611	24.815	31.019	37.222	43.426	49.630	55.833
.8	6.296	12.593	18.889	25.185	31.481	37.778	44.074	50.370	56.667
.9	6.389	12.778	19.167	25.556	31.944	38.333	44.722	51.111	57.500
7.0	6.481	12.963	19.444	25.926	32.407	38.889	45.370	51.852	58.333
.1	6.574	13.148	19.722	26.296	32.870	39.444	46.019	52.593	59.167
.2	6.667	13.333	20.000	26.667	33.333	40.000	46.667	53.333	60.000
.3	6.759	13.519	20.278	27.037	33.796	40.556	47.315	54.074	60.833
.4	6.852	13.704	20.556	27.407	34.259	41.111	47.963	54.815	61.667
.5	6.944	13.889	20.833	27.778	34.722	41.667	48.611	55.556	62.500
.6	7.037	14.074	21.111	28.148	35.185	42.222	49.259	56.296	63.333
.7	7.130	14.259	21.389	28.519	35.648	42.778	49.907	57.037	64.167
.8	7.222	14.444	21.667	28.889	36.111	43.333	50.556	57.778	65.000
.9	7.315	14.630	21.944	29.259	36.574	43.889	51.204	58.519	65.833
8.0	7.407	14.815	22.222	29.630	37.037	44.444	51.852	59.259	66.667
.1	7.500	15.000	22.500	30.000	37.500	45.000	52.500	60.000	67.500
.2	7.593	15.185	22.778	30.370	37.963	45.556	53.148	60.741	68.333
.3	7.685	15.370	23.056	30.741	38.426	46.111	53.796	61.481	69.167
.4	7.778	15.556	23.333	31.111	38.889	46.667	54.444	62.222	70.000
.5	7.870	15.741	23.611	31.481	39.352	47.222	55.093	62.963	70.833
.6	7.963	15.926	23.889	31.852	39.815	47.778	55.741	63.704	71.667
.7	8.056	16.111	24.167	32.222	40.278	48.333	56.389	64.444	72.500
.8	8.148	16.296	24.444	32.593	40.741	48.889	57.037	65.185	73.333
.9	8.241	16.481	24.722	32.963	41.204	49.444	57.685	65.926	74.167
9.0	8.333	16.667	25.000	33.333	41.667	50.000	58.333	66.667	75.000
.1	8.426	16.852	25.278	33.704	42.130	50.556	58.981	67.407	75.833
.2	8.519	17.037	25.556	34.074	42.593	51.111	59.630	68.148	76.667
.3	8.611	17.222	25.833	34.444	43.056	51.667	60.278	68.889	77.500
.4	8.704	17.407	26.111	34.815	43.519	52.222	60.926	69.630	78.333
.5	8.796	17.593	26.389	35.185	43.981	52.778	61.574	70.370	79.167
.6	8.889	17.778	26.667	35.556	44.444	53.333	62.222	71.111	80.000
.7	8.981	17.963	26.944	35.926	44.907	53.889	62.870	71.852	80.833
.8	9.074	18.148	27.222	36.296	45.370	54.444	63.519	72.593	81.667
.9	9.167	18.333	27.500	36.667	45.833	55.000	64.167	73.333	82.500
10.0	9.259	18.519	27.778	37.037	46.296	55.556	64.815	74.074	83.333
.1	9.352	18.704	28.056	37.407	46.759	56.111	65.463	74.815	84.167
.2	9.444	18.889	28.333	37.778	47.222	56.667	66.111	75.556	85.000
.3	9.537	19.074	28.611	38.148	47.685	57.222	66.759	76.296	85.833
.4	9.630	19.259	28.889	38.519	48.148	57.778	67.407	77.037	86.667
.5	9.722	19.444	29.167	38.889	48.611	58.333	68.056	77.778	87.500
.6	9.815	19.630	29.444	39.259	49.074	58.889	68.704	78.519	88.333
.7	9.907	19.815	29.722	39.630	49.537	59.444	69.352	79.259	89.167
.8	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000
.9	10.093	20.185	30.278	40.370	50.463	60.556	70.648	80.741	90.833
11.0	10.185	20.370	30.556	40.741	50.926	61.111	71.296	81.481	91.667
.1	10.278	20.556	30.833	41.111	51.389	61.667	71.944	82.222	92.500
.2	10.370	20.741	31.111	41.481	51.852	62.222	72.593	82.963	93.333
.3	10.463	20.926	31.389	41.852	52.315	62.778	73.241	83.704	94.167
.4	10.556	21.111	31.667	42.222	52.778	63.333	73.889	84.444	95.000
.5	10.648	21.296	31.944	42.593	53.241	63.889	74.537	85.185	95.833
.6	10.741	21.481	32.222	42.963	53.704	64.444	75.185	85.926	96.667
.7	10.833	21.667	32.500	43.333	54.167	65.000	75.833	86.667	97.500
.8	10.926	21.852	32.778	43.704	54.630	65.556	76.481	87.407	98.333
.9	11.019	22.037	33.056	44.074	55.093	66.111	77.130	88.148	99.167
12.0	11.111	22.222	33.333	44.444	55.556	66.667	77.778	88.889	100.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
12.1	11.204	22.407	33.611	44.815	56.019	67.222	78.426	89.630	100.833
.2	11.296	22.593	33.889	45.185	56.481	67.778	79.074	90.370	101.667
.3	11.389	22.778	34.167	45.556	56.944	68.333	79.722	91.111	102.500
.4	11.481	22.963	34.444	45.926	57.407	68.889	80.370	91.852	103.333
.5	11.574	23.148	34.722	46.296	57.870	69.444	81.019	92.593	104.167
.6	11.667	23.333	35.000	46.667	58.333	70.000	81.667	93.333	105.000
.7	11.759	23.519	35.278	47.037	58.796	70.556	82.315	94.074	105.833
.8	11.852	23.704	35.556	47.407	59.259	71.111	82.963	94.815	106.667
.9	11.944	23.889	35.833	47.778	59.722	71.667	83.611	95.556	107.500
13.0	12.037	24.074	36.111	48.148	60.185	72.222	84.259	96.296	108.333
.1	12.130	24.259	36.389	48.519	60.648	72.778	84.907	97.037	109.167
.2	12.222	24.444	36.667	48.889	61.111	73.333	85.556	97.778	110.000
.3	12.315	24.630	36.944	49.259	61.574	73.889	86.204	98.519	110.833
.4	12.407	24.815	37.222	49.630	62.037	74.444	86.852	99.259	111.667
.5	12.500	25.000	37.500	50.000	62.500	75.000	87.500	100.000	112.500
.6	12.593	25.185	37.778	50.370	62.963	75.556	88.148	100.741	113.333
.7	12.685	25.370	38.056	50.741	63.426	76.111	88.796	101.481	114.167
.8	12.778	25.556	38.333	51.111	63.889	76.667	89.444	102.222	115.000
.9	12.870	25.741	38.611	51.481	64.352	77.222	90.093	102.963	115.833
14.0	12.963	25.926	38.889	51.852	64.815	77.778	90.741	103.704	116.667
.1	13.056	26.111	39.167	52.222	65.278	78.333	91.389	104.444	117.500
.2	13.148	26.296	39.444	52.593	65.741	78.889	92.037	105.185	118.333
.3	13.241	26.481	39.722	52.963	66.204	79.444	92.685	105.926	119.167
.4	13.333	26.667	40.000	53.333	66.667	80.000	93.333	106.667	120.000
.5	13.426	26.852	40.278	53.704	67.130	80.556	93.981	107.407	120.833
.6	13.519	27.037	40.556	54.074	67.593	81.111	94.630	108.148	121.667
.7	13.611	27.222	40.833	54.444	68.056	81.667	95.278	108.889	122.500
.8	13.704	27.407	41.111	54.815	68.519	82.222	95.926	109.630	123.333
.9	13.796	27.593	41.389	55.185	68.981	82.778	96.574	110.370	124.167
15.0	13.889	27.778	41.667	55.556	69.444	83.333	97.222	111.111	125.000
.1	13.981	27.963	41.944	55.926	69.907	83.889	97.870	111.852	125.833
.2	14.074	28.148	42.222	56.296	70.370	84.444	98.519	112.593	126.667
.3	14.167	28.333	42.500	56.667	70.833	85.000	99.167	113.333	127.500
.4	14.259	28.519	42.778	57.037	71.296	85.556	99.815	114.074	128.333
.5	14.352	28.704	43.056	57.407	71.759	86.111	100.463	114.815	129.167
.6	14.444	28.889	43.333	57.778	72.222	86.667	101.111	115.556	130.000
.7	14.537	29.074	43.611	58.148	72.685	87.222	101.759	116.296	130.833
.8	14.630	29.259	43.889	58.519	73.148	87.778	102.407	117.037	131.667
.9	14.722	29.444	44.167	58.889	73.611	88.333	103.056	117.778	132.500
16.0	14.815	29.630	44.444	59.259	74.074	88.889	103.704	118.519	133.333
.1	14.907	29.815	44.722	59.630	74.537	89.444	104.352	119.259	134.167
.2	15.000	30.000	45.000	60.000	75.000	90.000	105.000	120.000	135.000
.3	15.093	30.185	45.278	60.370	75.463	90.556	105.648	120.741	135.833
.4	15.185	30.370	45.556	60.741	75.926	91.111	106.296	121.481	136.667
.5	15.278	30.556	45.833	61.111	76.389	91.667	106.944	122.222	137.500
.6	15.370	30.741	46.111	61.481	76.852	92.222	107.593	122.963	138.333
.7	15.463	30.926	46.389	61.852	77.315	92.778	108.241	123.704	139.167
.8	15.556	31.111	46.667	62.222	77.778	93.333	108.889	124.444	140.000
.9	15.648	31.296	46.944	62.593	78.241	93.889	109.537	125.185	140.833
17.0	15.741	31.481	47.222	62.963	78.704	94.444	110.185	125.926	141.667
.1	15.833	31.667	47.500	63.333	79.167	95.000	110.833	126.667	142.500
.2	15.926	31.852	47.778	63.704	79.630	95.556	111.481	127.407	143.333
.3	16.019	32.037	48.056	64.074	80.093	96.111	112.130	128.148	144.167
.4	16.111	32.222	48.333	64.444	80.556	96.667	112.778	128.889	145.000
.5	16.204	32.407	48.611	64.815	81.019	97.222	113.426	129.630	145.833
.6	16.296	32.593	48.889	65.185	81.481	97.778	114.074	130.370	146.667
.7	16.389	32.778	49.167	65.556	81.944	98.333	114.722	131.111	147.500
.8	16.481	32.963	49.444	65.926	82.407	98.889	115.370	131.852	148.333
.9	16.574	33.148	49.722	66.296	82.870	99.444	116.019	132.593	149.167
18.0	16.667	33.333	50.000	66.667	83.333	100.000	116.667	133.333	150.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
18.1	16.759	33.519	50.278	67.037	83.796	100.556	117.315	134.074	150.833
.2	16.852	33.704	50.556	67.407	84.259	101.111	117.963	134.815	151.667
.3	16.944	33.889	50.833	67.778	84.722	101.667	118.611	135.556	152.500
.4	17.037	34.074	51.111	68.148	85.185	102.222	119.259	136.296	153.333
.5	17.130	34.259	51.389	68.519	85.648	102.778	119.907	137.037	154.166
.6	17.222	34.444	51.667	68.889	86.111	103.333	120.556	137.778	155.000
.7	17.315	34.630	51.944	69.259	86.574	103.889	121.204	138.519	155.833
.8	17.407	34.815	52.222	69.630	87.037	104.444	121.852	139.259	156.667
.9	17.500	35.000	52.500	70.000	87.500	105.000	122.500	140.000	157.500
19.0	17.593	35.185	52.778	70.370	87.963	105.556	123.148	140.741	158.333
.1	17.685	35.370	53.056	70.741	88.426	106.111	123.796	141.481	159.167
.2	17.778	35.556	53.333	71.111	88.889	106.667	124.444	142.222	160.000
.3	17.870	35.741	53.611	71.481	89.352	107.222	125.093	142.963	160.833
.4	17.963	35.926	53.889	71.852	89.815	107.778	125.741	143.704	161.667
.5	18.056	36.111	54.167	72.222	90.278	108.333	126.389	144.444	162.500
.6	18.148	36.296	54.444	72.593	90.741	108.889	127.037	145.185	163.333
.7	18.241	36.481	54.722	72.963	91.204	109.444	127.685	145.926	164.167
.8	18.333	36.667	55.000	73.333	91.667	110.000	128.333	146.667	165.000
.9	18.426	36.852	55.278	73.704	92.130	110.556	128.981	147.407	165.833
20.0	18.519	37.037	55.556	74.074	92.593	111.111	129.630	148.148	166.667
.1	18.611	37.222	55.833	74.444	93.056	111.667	130.278	148.889	167.500
.2	18.704	37.407	56.111	74.815	93.519	112.222	130.926	149.630	168.333
.3	18.796	37.593	56.389	75.185	93.981	112.778	131.574	150.370	169.167
.4	18.889	37.778	56.667	75.556	94.444	113.333	132.222	151.111	170.000
.5	18.981	37.963	56.944	75.926	94.907	113.889	132.870	151.852	170.833
.6	19.074	38.148	57.222	76.296	95.370	114.444	133.519	152.593	171.667
.7	19.167	38.333	57.500	76.667	95.833	115.000	134.167	153.333	172.500
.8	19.259	38.519	57.778	77.037	96.296	115.556	134.815	154.074	173.333
.9	19.352	38.704	58.056	77.407	96.759	116.111	135.463	154.815	174.167
21.0	19.444	38.889	58.333	77.778	97.222	116.667	136.111	155.556	175.000
.1	19.537	39.074	58.611	78.148	97.685	117.222	136.759	156.296	175.833
.2	19.630	39.259	58.889	78.519	98.148	117.778	137.407	157.037	176.667
.3	19.722	39.444	59.167	78.889	98.611	118.333	138.056	157.778	177.500
.4	19.815	39.630	59.444	79.259	99.074	118.889	138.704	158.519	178.333
.5	19.907	39.815	59.722	79.630	99.537	119.444	139.352	159.259	179.167
.6	20.000	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000
.7	20.093	40.185	60.278	80.370	100.463	120.556	140.648	160.741	180.833
.8	20.185	40.370	60.556	80.741	100.926	121.111	141.296	161.481	181.667
.9	20.278	40.556	60.833	81.111	101.389	121.667	141.944	162.222	182.500
22.0	20.370	40.741	61.111	81.481	101.852	122.222	142.593	162.963	183.333
.1	20.463	40.926	61.389	81.852	102.315	122.778	143.241	163.704	184.166
.2	20.556	41.111	61.667	82.222	102.778	123.333	143.889	164.444	185.000
.3	20.648	41.296	61.944	82.593	103.241	123.889	144.537	165.185	185.833
.4	20.741	41.481	62.222	82.963	103.704	124.444	145.185	165.926	186.667
.5	20.833	41.667	62.500	83.333	104.167	125.000	145.833	166.667	187.500
.6	20.926	41.852	62.778	83.704	104.630	125.556	146.481	167.407	188.333
.7	21.019	42.037	63.056	84.074	105.093	126.111	147.130	168.148	189.167
.8	21.111	42.222	63.333	84.444	105.556	126.667	147.778	168.889	190.000
.9	21.204	42.407	63.611	84.815	106.019	127.222	148.426	169.630	190.833
23.0	21.296	42.593	63.889	85.185	106.481	127.778	149.074	170.370	191.667
.1	21.389	42.778	64.167	85.556	106.944	128.333	149.722	171.111	192.500
.2	21.481	42.963	64.444	85.926	107.407	128.889	150.370	171.852	193.333
.3	21.574	43.148	64.722	86.296	107.870	129.444	151.019	172.593	194.167
.4	21.667	43.333	65.000	86.667	108.333	130.000	151.667	173.333	195.000
.5	21.759	43.519	65.278	87.037	108.796	130.556	152.315	174.074	195.833
.6	21.852	43.704	65.556	87.407	109.259	131.111	152.963	174.815	196.667
.7	21.944	43.889	65.833	87.778	109.722	131.667	153.611	175.556	197.500
.8	22.037	44.074	66.111	88.148	110.185	132.222	154.259	176.296	198.333
.9	22.130	44.259	66.389	88.519	110.648	132.778	154.907	177.037	199.167
24.0	22.222	44.444	66.667	88.889	111.111	133.333	155.556	177.778	200.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
24.1	22.315	44.630	66.944	89.259	111.574	133.889	156.204	178.519	200.833
.2	22.407	44.815	67.222	89.630	112.037	134.444	156.852	179.259	201.667
.3	22.500	45.000	67.500	90.000	112.500	135.000	157.500	180.000	202.500
.4	22.593	45.185	67.778	90.370	112.963	135.556	158.148	180.741	203.333
.5	22.685	45.370	68.056	90.741	113.426	136.111	158.796	181.481	204.167
.6	22.778	45.556	68.333	91.111	113.889	136.667	159.444	182.222	205.000
.7	22.870	45.741	68.611	91.481	114.352	137.222	160.093	182.963	205.833
.8	22.963	45.926	68.889	91.852	114.815	137.778	160.741	183.704	206.667
.9	23.056	46.111	69.167	92.222	115.278	138.333	161.389	184.444	207.500
25.0	23.148	46.296	69.444	92.593	115.741	138.889	162.037	185.185	208.333
.1	23.241	46.481	69.722	92.963	116.204	139.444	162.685	185.926	209.167
.2	23.333	46.667	70.000	93.333	116.667	140.000	163.333	186.667	210.000
.3	23.426	46.852	70.278	93.704	117.130	140.556	163.981	187.407	210.833
.4	23.519	47.037	70.556	94.074	117.593	141.111	164.630	188.148	211.667
.5	23.611	47.222	70.833	94.444	118.056	141.667	165.278	188.889	212.500
.6	23.704	47.407	71.111	94.815	118.519	142.222	165.926	189.630	213.333
.7	23.796	47.593	71.389	95.185	118.981	142.778	166.574	190.370	214.167
.8	23.889	47.778	71.667	95.556	119.444	143.333	167.222	191.111	215.000
.9	23.981	47.963	71.944	95.926	119.907	143.889	167.870	191.852	215.833
26.0	24.074	48.148	72.222	96.296	120.370	144.444	168.519	192.593	216.667
.1	24.167	48.333	72.500	96.667	120.833	145.000	169.167	193.333	217.500
.2	24.259	48.519	72.778	97.074	121.296	145.556	169.815	194.074	218.333
.3	24.352	48.704	73.056	97.407	121.759	146.111	170.463	194.815	219.167
.4	24.444	48.889	73.333	97.778	122.222	146.667	171.111	195.556	220.000
.5	24.537	49.074	73.611	98.148	122.685	147.222	171.759	196.296	220.833
.6	24.630	49.259	73.889	98.519	123.148	147.778	172.407	197.037	221.667
.7	24.722	49.444	74.167	98.889	123.611	148.333	173.056	197.778	222.500
.8	24.815	49.630	74.444	99.259	124.074	148.889	173.704	198.519	223.333
.9	24.907	49.815	74.722	99.630	124.537	149.444	174.352	199.259	224.167
27.0	25.000	50.000	75.000	100.000	125.000	150.000	175.000	200.000	225.000
.1	25.093	50.185	75.278	100.370	125.463	150.556	175.648	200.741	225.833
.2	25.185	50.370	75.556	100.741	125.926	151.111	176.296	201.481	226.667
.3	25.278	50.556	75.833	101.111	126.389	151.667	176.944	202.222	227.500
.4	25.370	50.741	76.111	101.481	126.852	152.222	177.593	202.963	228.333
.5	25.463	50.926	76.389	101.852	127.315	152.778	178.241	203.704	229.167
.6	25.556	51.111	76.667	102.222	127.778	153.333	178.889	204.444	230.000
.7	25.648	51.296	76.944	102.593	128.241	153.889	179.537	205.185	230.833
.8	25.741	51.481	77.222	102.963	128.704	154.444	180.185	205.926	231.667
.9	25.833	51.667	77.500	103.333	129.167	155.000	180.833	206.667	232.500
28.0	25.926	51.852	77.778	103.704	129.630	155.556	181.481	207.407	233.333
.1	26.019	52.037	78.056	104.074	130.093	156.111	182.130	208.148	234.167
.2	26.111	52.222	78.333	104.444	130.556	156.667	182.778	208.889	235.000
.3	26.204	52.407	78.611	104.815	131.019	157.222	183.426	209.630	235.833
.4	26.296	52.593	78.889	105.185	131.481	157.778	184.074	210.370	236.667
.5	26.389	52.778	79.167	105.556	131.944	158.333	184.722	211.111	237.500
.6	26.481	52.963	79.444	105.926	132.407	158.889	185.370	211.852	238.333
.7	26.574	53.148	79.722	106.296	132.870	159.444	186.019	212.593	239.167
.8	26.667	53.333	80.000	106.667	133.333	160.000	186.667	213.333	240.000
.9	26.759	53.519	80.278	107.037	133.796	160.556	187.315	214.074	240.833
29.0	26.852	53.704	80.556	107.407	134.259	161.111	187.963	214.815	241.667
.1	26.944	53.889	80.833	107.778	134.722	161.667	188.611	215.556	242.500
.2	27.037	54.074	81.111	108.148	135.185	162.222	189.259	216.296	243.333
.3	27.130	54.259	81.389	108.519	135.648	162.778	189.907	217.037	244.167
.4	27.222	54.444	81.667	108.889	136.111	163.333	190.556	217.778	245.000
.5	27.315	54.630	81.944	109.259	136.574	163.889	191.204	218.519	245.833
.6	27.407	54.815	82.222	109.630	137.037	164.444	191.852	219.259	246.667
.7	27.500	55.000	82.500	110.000	137.500	165.000	192.500	220.000	247.500
.8	27.593	55.185	82.778	110.370	137.963	165.556	193.148	220.741	248.333
.9	27.685	55.370	83.056	110.741	138.426	166.111	193.796	221.481	249.167
30.0	27.778	55.556	83.333	111.111	138.889	166.667	194.444	222.222	250.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
30.1	27.870	55.741	83.611	111.481	139.352	167.222	195.093	222.963	250.833
.2	27.963	55.926	83.889	111.852	139.815	167.778	195.741	223.704	251.667
.3	28.056	56.111	84.167	112.222	140.278	168.333	196.389	224.444	252.500
.4	28.148	56.296	84.444	112.593	140.741	168.889	197.037	225.185	253.333
.5	28.241	56.481	84.722	112.963	141.204	169.444	197.685	225.926	254.167
.6	28.333	56.667	85.000	113.333	141.667	170.000	198.333	226.667	255.000
.7	28.426	56.852	85.278	113.704	142.130	170.556	198.981	227.407	255.833
.8	28.519	57.037	85.556	114.074	142.593	171.111	199.630	228.148	256.667
.9	28.611	57.222	85.833	114.444	143.056	171.667	200.278	228.889	257.500
31.0	28.704	57.407	86.111	114.815	143.519	172.222	200.926	229.630	258.333
.1	28.796	57.593	86.389	115.185	143.981	172.778	201.574	230.370	259.167
.2	28.889	57.778	86.667	115.556	144.444	173.333	202.222	231.111	260.000
.3	28.981	57.963	86.944	115.926	144.907	173.889	202.870	231.852	260.833
.4	29.074	58.148	87.222	116.296	145.370	174.444	203.519	232.593	261.667
.5	29.167	58.333	87.500	116.667	145.833	175.000	204.167	233.333	262.500
.6	29.259	58.519	87.778	117.037	146.296	175.556	204.815	234.074	263.333
.7	29.352	58.704	88.056	117.407	146.759	176.111	205.463	234.815	264.167
.8	29.444	58.889	88.333	117.778	147.222	176.667	206.111	235.556	265.000
.9	29.537	59.074	88.611	118.148	147.685	177.222	206.759	236.296	265.833
32.0	29.630	59.259	88.889	118.519	148.148	177.778	207.407	237.037	266.667
.1	29.722	59.444	89.167	118.889	148.611	178.333	208.056	237.778	267.500
.2	29.815	59.630	89.444	119.259	149.074	178.889	208.704	238.519	268.333
.3	29.907	59.815	89.722	119.630	149.537	179.444	209.352	239.259	269.167
.4	30.000	60.000	90.000	120.000	150.000	180.000	210.000	240.000	270.000
.5	30.093	60.185	90.278	120.370	150.463	180.556	210.648	240.741	270.833
.6	30.185	60.370	90.556	120.741	150.926	181.111	211.296	241.481	271.667
.7	30.278	60.556	90.833	121.111	151.389	181.667	211.944	242.222	272.500
.8	30.370	60.741	91.111	121.481	151.852	182.222	212.593	242.963	273.333
.9	30.463	60.926	91.389	121.852	152.315	182.778	213.241	243.704	274.167
33.0	30.556	61.111	91.667	122.222	152.778	183.333	213.889	244.444	275.000
.1	30.648	61.296	91.944	122.593	153.241	183.889	214.537	245.185	275.833
.2	30.741	61.481	92.222	122.963	153.704	184.444	215.185	245.926	276.667
.3	30.833	61.667	92.500	123.333	154.167	185.000	215.833	246.667	277.500
.4	30.926	61.852	92.778	123.704	154.630	185.556	216.481	247.407	278.333
.5	31.019	62.037	93.056	124.074	155.093	186.111	217.130	248.148	279.167
.6	31.111	62.222	93.333	124.444	155.556	186.667	217.778	248.889	280.000
.7	31.204	62.407	93.611	124.815	156.019	187.222	218.426	249.630	280.833
.8	31.296	62.593	93.889	125.185	156.481	187.778	219.074	250.370	281.667
.9	31.389	62.778	94.167	125.556	156.944	188.333	219.722	251.111	282.500
34.0	31.481	62.963	94.444	125.926	157.407	188.889	220.370	251.852	283.333
.1	31.574	63.148	94.722	126.296	157.870	189.444	221.019	252.593	284.167
.2	31.667	63.333	95.000	126.667	158.333	190.000	221.667	253.333	285.000
.3	31.759	63.519	95.278	127.037	158.796	190.556	222.315	254.074	285.833
.4	31.852	63.704	95.556	127.407	159.259	191.111	222.963	254.815	286.667
.5	31.944	63.889	95.833	127.778	159.722	191.667	223.611	255.556	287.500
.6	32.037	64.074	96.111	128.148	160.185	192.222	224.259	256.296	288.333
.7	32.130	64.259	96.389	128.519	160.648	192.778	224.907	257.037	289.167
.8	32.222	64.444	96.667	128.889	161.111	193.333	225.556	257.778	290.000
.9	32.315	64.630	96.944	129.259	161.574	193.889	226.204	258.519	290.833
35.0	32.407	64.815	97.222	129.630	162.037	194.444	226.852	259.259	291.667
.1	32.500	65.000	97.500	130.000	162.500	195.000	227.500	260.000	292.500
.2	32.593	65.185	97.778	130.370	162.963	195.556	228.148	260.741	293.333
.3	32.685	65.370	98.056	130.741	163.426	196.111	228.796	261.481	294.167
.4	32.778	65.556	98.333	131.111	163.889	196.667	229.444	262.222	295.000
.5	32.870	65.741	98.611	131.481	164.352	197.222	230.093	262.963	295.833
.6	32.963	65.926	98.889	131.852	164.815	197.778	230.741	263.704	296.667
.7	33.056	66.111	99.167	132.222	165.278	198.333	231.389	264.444	297.500
.8	33.148	66.296	99.444	132.593	165.741	198.889	232.037	265.185	298.333
.9	33.241	66.481	99.722	132.963	166.204	199.444	232.685	265.926	299.167
36.0	33.333	66.667	100.000	133.333	166.667	200.000	233.333	266.667	300.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
36.1	33.426	66.852	100.278	133.704	167.130	200.556	233.981	267.407	300.833
.2	33.519	67.037	100.556	134.074	167.593	201.111	234.630	268.148	301.667
.3	33.611	67.222	100.833	134.444	168.056	201.667	235.278	268.889	302.500
.4	33.704	67.407	101.111	134.815	168.519	202.222	235.926	269.630	303.333
.5	33.796	67.593	101.389	135.185	168.981	202.778	236.574	270.370	304.167
.6	33.889	67.778	101.667	135.556	169.444	203.333	237.222	271.111	305.000
.7	33.981	67.963	101.944	135.926	169.907	203.889	237.870	271.852	305.833
.8	34.074	68.148	102.222	136.296	170.370	204.444	238.519	272.593	306.667
.9	34.167	68.333	102.500	136.667	170.833	205.000	239.167	273.333	307.500
37.0	34.259	68.519	102.778	137.037	171.296	205.556	239.815	274.074	308.333
.1	34.352	68.704	103.056	137.407	171.759	206.111	240.463	274.815	309.167
.2	34.444	68.889	103.333	137.778	172.222	206.667	241.111	275.556	310.000
.3	34.537	69.074	103.611	138.148	172.685	207.222	241.759	276.296	310.833
.4	34.630	69.259	103.889	138.519	173.148	207.778	242.407	277.037	311.667
.5	34.722	69.444	104.167	138.889	173.611	208.333	243.056	277.778	312.500
.6	34.815	69.630	104.444	139.259	174.074	208.889	243.704	278.519	313.333
.7	34.907	69.815	104.722	139.630	174.537	209.444	244.352	279.259	314.167
.8	35.000	70.000	105.000	140.000	175.000	210.000	245.000	280.000	315.000
.9	35.093	70.185	105.278	140.370	175.463	210.556	245.648	280.741	315.833
38.0	35.185	70.370	105.556	140.741	175.926	211.111	246.296	281.481	316.667
.1	35.278	70.556	105.833	141.111	176.389	211.667	246.944	282.222	317.500
.2	35.370	70.741	106.111	141.481	176.852	212.222	247.593	282.963	318.333
.3	35.463	70.926	106.389	141.852	177.315	212.778	248.241	283.704	319.167
.4	35.556	71.111	106.667	142.222	177.778	213.333	248.889	284.444	320.000
.5	35.648	71.296	106.944	142.593	178.241	213.889	249.537	285.185	320.833
.6	35.741	71.481	107.222	142.963	178.704	214.444	250.185	285.926	321.667
.7	35.833	71.667	107.500	143.333	179.167	215.000	250.833	286.667	322.500
.8	35.926	71.852	107.778	143.704	179.630	215.556	251.481	287.407	323.333
.9	36.019	72.037	108.056	144.074	180.093	216.111	252.130	288.148	324.167
39.0	36.111	72.222	108.333	144.444	180.556	216.667	252.778	288.889	325.000
.1	36.204	72.407	108.611	144.815	181.019	217.222	253.426	289.630	325.833
.2	36.296	72.593	108.889	145.185	181.481	217.778	254.074	290.370	326.667
.3	36.389	72.778	109.167	145.556	181.944	218.333	254.722	291.111	327.500
.4	36.481	72.963	109.444	145.926	182.407	218.889	255.370	291.852	328.333
.5	36.574	73.148	109.722	146.296	182.870	219.444	256.019	292.593	329.167
.6	36.667	73.333	110.000	146.667	183.333	220.000	256.667	293.333	330.000
.7	36.759	73.519	110.278	147.037	183.796	220.556	257.315	294.074	330.833
.8	36.852	73.704	110.556	147.407	184.259	221.111	257.963	294.815	331.667
.9	36.944	73.889	110.833	147.778	184.722	221.667	258.611	295.556	332.500
40.0	37.037	74.074	111.111	148.148	185.185	222.222	259.259	296.296	333.333
.1	37.130	74.259	111.389	148.519	185.648	222.778	259.907	297.037	334.167
.2	37.222	74.444	111.667	148.889	186.111	223.333	260.556	297.778	335.000
.3	37.315	74.630	111.944	149.259	186.574	223.889	261.204	298.519	335.833
.4	37.407	74.815	112.222	149.630	187.037	224.444	261.852	299.259	336.667
.5	37.500	75.000	112.500	150.000	187.500	225.000	262.500	300.000	337.500
.6	37.593	75.185	112.778	150.370	187.963	225.556	263.148	300.741	338.333
.7	37.685	75.370	113.056	150.741	188.426	226.111	263.796	301.481	339.167
.8	37.778	75.556	113.333	151.111	188.889	226.667	264.444	302.222	340.000
.9	37.870	75.741	113.611	151.481	189.352	227.222	265.093	302.963	340.833
41.0	37.963	75.926	113.889	151.852	189.815	227.778	265.741	303.704	341.667
.1	38.056	76.111	114.167	152.222	190.278	228.333	266.389	304.444	342.500
.2	38.148	76.296	114.444	152.593	190.741	228.889	267.037	305.185	343.333
.3	38.241	76.481	114.722	152.963	191.204	229.444	267.685	305.926	344.167
.4	38.333	76.667	115.000	153.333	191.667	230.000	268.333	306.667	345.000
.5	38.426	76.852	115.278	153.704	192.130	230.556	268.981	307.407	345.833
.6	38.519	77.037	115.556	154.074	192.593	231.111	269.630	308.148	346.667
.7	38.611	77.222	115.833	154.444	193.056	231.667	270.278	308.889	347.500
.8	38.704	77.407	116.111	154.815	193.519	232.222	270.926	309.630	348.333
.9	38.796	77.593	116.389	155.185	193.981	232.778	271.574	310.370	349.167
42.0	38.889	77.778	116.667	155.556	194.444	233.333	272.222	311.111	350.000

WIDTH.

Hgt.	1	2	3	4	5	6	7	8	9
42.1	38.981	77.963	116.944	155.926	194.907	233.889	272.870	311.852	350.833
.2	39.074	78.148	117.222	156.296	195.370	234.444	273.519	312.593	351.667
.3	39.167	78.333	117.500	156.667	195.833	235.000	274.167	313.333	352.500
.4	39.259	78.519	117.778	157.037	196.296	235.556	274.815	314.074	353.333
.5	39.352	78.704	118.056	157.407	196.759	236.111	275.463	314.815	354.167
.6	39.444	78.889	118.333	157.778	197.222	236.667	276.111	315.556	355.000
.7	39.537	79.074	118.611	158.148	197.685	237.222	276.759	316.296	355.833
.8	39.630	79.259	118.889	158.519	198.148	237.778	277.407	317.037	356.667
.9	39.722	79.444	119.167	158.889	198.611	238.333	278.056	317.778	357.500
43.0	39.815	79.630	119.444	159.259	199.074	238.889	278.704	318.519	358.333
.1	39.907	79.815	119.722	159.630	199.537	239.444	279.352	319.259	359.167
.2	40.000	80.000	120.000	160.000	200.000	240.000	280.000	320.000	360.000
.3	40.093	80.185	120.278	160.370	200.463	240.556	280.648	320.741	360.833
.4	40.185	80.370	120.556	160.741	200.926	241.111	281.296	321.481	361.667
.5	40.278	80.556	120.833	161.111	201.389	241.667	281.944	322.222	362.500
.6	40.370	80.741	121.111	161.481	201.852	242.222	282.593	322.963	363.333
.7	40.463	80.926	121.389	161.852	202.315	242.778	283.241	323.704	364.167
.8	40.556	81.111	121.667	162.222	202.778	243.333	283.889	324.444	365.000
.9	40.648	81.296	121.944	162.593	203.241	243.889	284.537	325.185	365.833
44.0	40.741	81.481	122.222	162.963	203.704	244.444	285.185	325.926	366.667
.1	40.833	81.667	122.500	163.333	204.167	245.000	285.833	326.667	367.500
.2	40.926	81.852	122.778	163.704	204.630	245.556	286.481	327.407	368.333
.3	41.019	82.037	123.056	164.074	205.093	246.111	287.130	328.148	369.167
.4	41.111	82.222	123.333	164.444	205.556	246.667	287.778	328.889	370.000
.5	41.204	82.407	123.611	164.815	206.019	247.222	288.426	329.630	370.833
.6	41.296	82.593	123.889	165.185	206.481	247.778	289.074	330.370	371.667
.7	41.389	82.778	124.167	165.556	206.944	248.333	289.722	331.111	372.500
.8	41.481	82.963	124.444	165.926	207.407	248.889	290.370	331.852	373.333
.9	41.574	83.148	124.722	166.296	207.870	249.444	291.019	332.593	374.167
45.0	41.667	83.333	125.000	166.667	208.333	250.000	291.667	333.333	375.000
.1	41.759	83.519	125.278	167.037	208.796	250.556	292.315	334.074	375.833
.2	41.852	83.704	125.556	167.407	209.259	251.111	292.963	334.815	376.667
.3	41.944	83.889	125.833	167.778	209.722	251.667	293.611	335.556	377.500
.4	42.037	84.074	126.111	168.148	210.185	252.222	294.259	336.296	378.333
.5	42.130	84.259	126.389	168.519	210.648	252.778	294.907	337.037	379.167
.6	42.222	84.444	126.667	168.889	211.111	253.333	295.556	337.778	380.000
.7	42.315	84.630	126.944	169.259	211.574	253.889	296.204	338.519	380.833
.8	42.407	84.815	127.222	169.630	212.037	254.444	296.852	339.259	381.667
.9	42.500	85.000	127.500	170.000	212.500	255.000	297.500	340.000	382.500
46.0	42.593	85.185	127.778	170.370	212.963	255.556	298.148	340.741	383.333
.1	42.685	85.370	128.056	170.741	213.426	256.111	298.796	341.481	384.167
.2	42.778	85.556	128.333	171.111	213.889	256.667	299.444	342.222	385.000
.3	42.870	85.741	128.611	171.481	214.352	257.222	300.093	342.963	385.833
.4	42.963	85.926	128.889	171.852	214.815	257.778	300.741	343.704	386.667
.5	43.056	86.111	129.167	172.222	215.278	258.333	301.389	344.444	387.500
.6	43.148	86.296	129.444	172.593	215.741	258.889	302.037	345.185	388.333
.7	43.241	86.481	129.722	172.963	216.204	259.444	302.685	345.926	389.167
.8	43.333	86.667	130.000	173.333	216.667	260.000	303.333	346.667	390.000
.9	43.426	86.852	130.278	173.704	217.130	260.556	303.981	347.407	390.833
47.0	43.519	87.037	130.556	174.074	217.593	261.111	304.630	348.148	391.667
.1	43.611	87.222	130.833	174.444	218.056	261.667	305.278	348.889	392.500
.2	43.704	87.407	131.111	174.815	218.519	262.222	305.926	349.630	393.333
.3	43.796	87.593	131.389	175.185	218.981	262.778	306.574	350.370	394.167
.4	43.889	87.778	131.667	175.556	219.444	263.333	307.222	351.111	395.000
.5	43.981	87.963	131.944	175.926	219.907	263.889	307.870	351.852	395.833
.6	44.074	88.148	132.222	176.296	220.370	264.444	308.519	352.593	396.667
.7	44.167	88.333	132.500	176.667	220.833	265.000	309.167	353.333	397.500
.8	44.259	88.519	132.778	177.037	221.296	265.556	309.815	354.074	398.333
.9	44.352	88.704	133.056	177.407	221.759	266.111	310.463	354.815	399.167
48.0	44.444	88.889	133.333	177.778	222.222	266.667	311.111	355.556	400.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
48.1	44.537	89.074	133.611	178.148	222.685	267.222	311.759	356.296	400.833
.2	44.630	89.259	133.889	178.519	223.148	267.778	312.407	357.037	401.667
.3	44.722	89.444	134.167	178.889	223.611	268.333	313.056	357.778	402.500
.4	44.815	89.630	134.444	179.259	224.074	268.889	313.704	358.519	403.333
.5	44.907	89.815	134.722	179.630	224.537	269.444	314.352	359.259	404.167
.6	45.000	90.000	135.000	180.000	225.000	270.000	315.000	360.000	405.000
.7	45.093	90.185	135.278	180.370	225.463	270.556	315.648	360.741	405.833
.8	45.185	90.370	135.556	180.741	225.926	271.111	316.296	361.481	406.667
.9	45.278	90.556	135.833	181.111	226.389	271.667	316.944	362.222	407.500
49.0	45.370	90.741	136.111	181.481	226.852	272.222	317.593	362.963	408.333
.1	45.463	90.926	136.389	181.852	227.315	272.778	318.241	363.704	409.167
.2	45.556	91.111	136.667	182.222	227.778	273.333	318.889	364.444	410.000
.3	45.648	91.296	136.944	182.593	228.241	273.889	319.537	365.185	410.833
.4	45.741	91.481	137.222	182.963	228.704	274.444	320.185	365.926	411.667
.5	45.833	91.667	137.500	183.333	229.167	275.000	320.833	366.667	412.500
.6	45.926	91.852	137.778	183.704	229.630	275.556	321.481	367.407	413.333
.7	46.019	92.037	138.056	184.074	230.093	276.111	322.130	368.148	414.167
.8	46.111	92.222	138.333	184.444	230.556	276.667	322.778	368.889	415.000
.9	46.204	92.407	138.611	184.815	231.019	277.222	323.426	369.630	415.833
50.0	46.296	92.593	138.889	185.185	231.481	277.778	324.074	370.370	416.667
.1	46.389	92.778	139.167	185.556	231.944	278.333	324.722	371.111	417.500
.2	46.481	92.963	139.444	185.926	232.407	278.889	325.370	371.852	418.333
.3	46.574	93.148	139.722	186.296	232.870	279.444	326.019	372.593	419.167
.4	46.667	93.333	140.000	186.667	233.333	280.000	326.667	373.333	420.000
.5	46.759	93.519	140.278	187.037	233.796	280.556	327.315	374.074	420.833
.6	46.852	93.704	140.556	187.407	234.259	281.111	327.963	374.815	421.667
.7	46.944	93.889	140.833	187.778	234.722	281.667	328.611	375.556	422.500
.8	47.037	94.074	141.111	188.148	235.185	282.222	329.259	376.296	423.333
.9	47.130	94.259	141.389	188.519	235.648	282.778	329.907	377.037	424.167
51.0	47.222	94.444	141.667	188.889	236.111	283.333	330.556	377.778	425.000
.1	47.315	94.630	141.944	189.259	236.574	283.889	331.204	378.519	425.833
.2	47.407	94.815	142.222	189.630	237.037	284.444	331.852	379.259	426.667
.3	47.500	95.000	142.500	190.000	237.500	285.000	332.500	380.000	427.500
.4	47.593	95.185	142.778	190.370	237.963	285.556	333.148	380.741	428.333
.5	47.685	95.370	143.056	190.741	238.426	286.111	333.796	381.481	429.167
.6	47.778	95.556	143.333	191.111	238.889	286.667	334.444	382.222	430.000
.7	47.870	95.741	143.611	191.481	239.352	287.222	335.093	382.963	430.833
.8	47.963	95.926	143.889	191.852	239.815	287.778	335.741	383.704	431.667
.9	48.056	96.111	144.167	192.222	240.278	288.333	336.389	384.444	432.500
52.0	48.148	96.296	144.444	192.593	240.741	288.889	337.037	385.185	433.333
.1	48.241	96.481	144.722	192.963	241.204	289.444	337.685	335.926	434.167
.2	48.333	96.667	145.000	193.333	241.667	290.000	338.333	386.667	435.000
.3	48.426	96.852	145.278	193.704	242.130	290.556	338.981	387.407	435.833
.4	48.519	97.037	145.556	194.074	242.593	291.111	339.630	388.148	436.667
.5	48.611	97.222	145.833	194.444	243.056	291.667	340.278	388.889	437.500
.6	48.704	97.407	146.111	194.815	243.519	292.222	340.926	389.630	438.333
.7	48.796	97.593	146.389	195.185	243.981	292.778	341.574	390.370	439.167
.8	48.889	97.778	146.667	195.556	244.444	293.333	342.222	391.111	440.000
.9	48.981	97.963	146.944	195.926	244.907	293.889	342.870	391.852	440.833
53.0	49.074	98.148	147.222	196.296	245.370	294.444	343.519	392.593	441.667
.1	49.167	98.333	147.500	196.667	245.833	295.000	344.167	393.333	442.500
.2	49.259	98.519	147.778	197.037	246.296	295.556	344.815	394.074	443.333
.3	49.352	98.704	148.056	197.407	246.759	296.111	345.463	394.815	444.167
.4	49.444	98.889	148.333	197.778	247.222	296.667	346.111	395.556	445.000
.5	49.537	99.074	148.611	198.148	247.685	297.222	346.759	396.296	445.833
.6	49.630	99.259	148.889	198.519	248.148	297.778	347.407	397.037	446.667
.7	49.722	99.444	149.167	198.889	248.611	298.333	348.056	397.778	447.500
.8	49.815	99.630	149.444	199.259	249.074	298.889	348.704	398.519	448.333
.9	49.907	99.815	149.722	199.630	249.537	299.444	349.352	399.259	449.167
54.0	50.000	100.000	150.000	200.000	250.000	300.000	350.000	400.000	450.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
54.1	50.093	100.185	150.278	200.370	250.463	300.556	350.648	400.741	450.833
.2	50.185	100.370	150.556	200.741	250.926	301.111	351.296	401.481	451.667
.3	50.278	100.556	150.833	201.111	251.389	301.667	351.944	402.222	452.500
.4	50.370	100.741	151.111	201.481	251.852	302.222	352.593	402.963	453.333
.5	50.463	100.926	151.389	201.852	252.315	302.778	353.241	403.704	454.167
.6	50.556	101.111	151.667	202.222	252.778	303.333	353.889	404.444	455.000
.7	50.648	101.296	151.944	202.593	253.241	303.889	354.537	405.185	455.833
.8	50.741	101.481	152.222	202.963	253.704	304.444	355.185	405.926	456.667
.9	50.833	101.667	152.500	203.333	254.167	305.000	355.833	406.667	457.500
55.0	50.926	101.852	152.778	203.704	254.630	305.556	356.481	407.407	458.333
.1	51.019	102.037	153.056	204.074	255.093	306.111	357.130	408.148	459.167
.2	51.111	102.222	153.333	204.444	255.556	306.667	357.778	408.889	460.000
.3	51.204	102.407	153.611	204.815	256.019	307.222	358.426	409.630	460.833
.4	51.296	102.593	153.889	205.185	256.481	307.778	359.074	410.370	461.667
.5	51.389	102.778	154.167	205.556	256.944	308.333	359.722	411.111	462.500
.6	51.481	102.963	154.444	205.926	257.407	308.889	360.370	411.852	463.333
.7	51.574	103.148	154.722	206.296	257.870	309.444	361.019	412.593	464.167
.8	51.667	103.333	155.000	206.667	258.333	310.000	361.667	413.333	465.000
.9	51.759	103.519	155.278	207.037	258.796	310.556	362.315	414.074	465.833
56.0	51.852	103.704	155.556	207.407	259.259	311.111	362.963	414.815	466.667
.1	51.944	103.889	155.833	207.778	259.722	311.667	363.611	415.556	467.500
.2	52.037	104.074	156.111	208.148	260.185	312.222	364.259	416.296	468.333
.3	52.130	104.259	156.389	208.519	260.648	312.778	364.907	417.037	469.167
.4	52.222	104.444	156.667	208.889	261.111	313.333	365.556	417.778	470.000
.5	52.315	104.630	156.944	209.259	261.574	313.889	366.204	418.519	470.833
.6	52.407	104.815	157.222	209.630	252.037	314.444	366.852	419.259	471.667
.7	52.500	105.000	157.500	210.000	262.500	315.000	367.500	420.000	472.500
.8	52.593	105.185	157.778	210.370	262.963	315.556	368.148	420.741	473.333
.9	52.685	105.370	158.056	210.741	263.426	316.111	368.796	421.481	474.167
57.0	52.778	105.556	158.333	211.111	263.889	316.667	369.444	422.222	475.000
.1	52.870	105.741	158.611	211.481	264.352	317.222	370.093	422.963	475.833
.2	52.963	105.926	158.889	211.852	264.815	317.778	370.741	423.704	476.667
.3	53.056	106.111	159.167	212.222	265.278	318.333	371.389	424.444	477.500
.4	53.148	106.296	159.444	212.593	265.741	318.889	372.037	425.185	478.333
.5	53.241	106.481	159.722	212.963	266.204	319.444	372.685	425.926	479.167
.6	53.333	106.667	160.000	213.333	266.667	320.000	373.333	426.667	480.000
.7	53.426	106.852	160.278	213.704	267.130	320.556	373.981	427.407	480.833
.8	53.519	107.037	160.556	214.074	267.593	321.111	374.630	428.148	481.667
.9	53.611	107.222	160.833	214.444	268.056	321.667	375.278	428.889	482.500
58.0	53.704	107.407	161.111	214.815	268.519	322.222	375.926	429.630	483.333
.1	53.796	107.593	161.389	215.185	268.981	322.778	376.574	430.370	484.167
.2	53.889	107.778	161.667	215.556	269.444	323.333	377.222	431.111	485.000
.3	53.981	107.963	161.944	215.926	269.907	323.889	377.870	431.852	485.833
.4	54.074	108.148	162.222	216.296	270.370	324.444	378.519	432.593	486.667
.5	54.167	108.333	162.500	216.667	270.833	325.000	379.167	433.333	487.500
.6	54.259	108.519	162.778	217.037	271.296	325.556	379.815	434.074	488.333
.7	54.352	108.704	163.056	217.407	271.759	326.111	380.463	434.815	489.167
.8	54.444	108.889	163.333	217.778	272.222	326.667	381.111	435.556	490.000
.9	54.537	109.074	163.611	218.148	272.685	327.222	381.759	436.296	490.833
59.0	54.630	109.259	163.889	218.519	273.148	327.778	382.407	437.037	491.667
.1	54.722	109.444	164.167	218.889	273.611	328.333	383.056	437.778	492.500
.2	54.815	109.630	164.444	219.259	274.074	328.889	383.704	438.519	493.333
.3	54.907	109.815	164.722	219.630	274.537	329.444	384.352	439.259	494.167
.4	55.000	110.000	165.000	220.000	275.000	330.000	385.000	440.000	495.000
.5	55.093	110.185	165.278	220.370	275.463	330.556	385.648	440.741	495.833
.6	55.185	110.370	165.556	220.741	275.926	331.111	386.296	441.481	496.667
.7	55.278	110.556	165.833	221.111	276.389	331.667	386.944	442.222	497.500
.8	55.370	110.741	166.111	221.481	276.852	332.222	387.593	442.963	498.333
.9	55.463	110.926	166.389	221.852	277.315	332.778	388.241	443.704	499.167
60.0	55.556	111.111	166.667	222.222	277.778	333.333	388.889	444.444	500.000

CU.YDS. PER 100 FT.

d-d'	1	2	3	4	5	6	7	8	9
D-D'									
0.1	.031	.062	.093	.123	.154	.185	.216	.247	.278
.2	.062	.123	.185	.247	.309	.370	.432	.494	.556
.3	.093	.185	.278	.370	.463	.556	.648	.741	.833
.4	.123	.247	.370	.494	.617	.741	.864	.988	1.111
.5	.154	.309	.463	.617	.772	.926	1.080	1.235	1.389
.6	.185	.370	.556	.741	.926	1.111	1.296	1.481	1.667
.7	.216	.432	.648	.864	1.080	1.296	1.512	1.728	1.944
.8	.247	.494	.741	.988	1.235	1.481	1.728	1.975	2.222
.9	.278	.556	.833	1.111	1.389	1.667	1.944	2.222	2.500
1.0	.309	.617	.926	1.235	1.543	1.852	2.160	2.469	2.778
.1	.340	.679	1.019	1.358	1.698	2.037	2.377	2.716	3.056
.2	.370	.741	1.111	1.481	1.852	2.222	2.593	2.963	3.333
.3	.401	.802	1.204	1.605	2.006	2.407	2.809	3.210	3.611
.4	.432	.864	1.296	1.728	2.160	2.593	3.025	3.457	3.889
.5	.463	.926	1.389	1.852	2.315	2.778	3.241	3.704	4.167
.6	.494	.988	1.481	1.975	2.469	2.963	3.457	3.951	4.444
.7	.525	1.049	1.574	2.099	2.623	3.148	3.673	4.198	4.722
.8	.556	1.111	1.667	2.222	2.778	3.333	3.889	4.444	5.000
.9	.586	1.173	1.759	2.346	2.932	3.519	4.105	4.691	5.278
2.0	.617	1.235	1.852	2.469	3.086	3.704	4.321	4.938	5.556
.1	.648	1.296	1.944	2.593	3.241	3.889	4.537	5.185	5.833
.2	.679	1.358	2.037	2.716	3.395	4.074	4.753	5.432	6.111
.3	.710	1.420	2.130	2.840	3.549	4.259	4.969	5.679	6.389
.4	.741	1.481	2.222	2.963	3.704	4.444	5.185	5.926	6.667
.5	.772	1.543	2.315	3.086	3.858	4.630	5.401	6.173	6.944
.6	.802	1.605	2.407	3.210	4.012	4.815	5.617	6.420	7.222
.7	.833	1.667	2.500	3.333	4.167	5.000	5.833	6.667	7.500
.8	.864	1.728	2.593	3.457	4.321	5.185	6.049	6.914	7.778
.9	.895	1.790	2.685	3.580	4.475	5.370	6.265	7.160	8.056
3.0	.926	1.852	2.778	3.704	4.630	5.556	6.481	7.407	8.333
.1	.957	1.914	2.870	3.827	4.784	5.741	6.698	7.654	8.611
.2	.988	1.975	2.963	3.951	4.938	5.926	6.914	7.901	8.889
.3	1.019	2.037	3.056	4.074	5.093	6.111	7.130	8.148	9.167
.4	1.049	2.099	3.148	4.198	5.247	6.296	7.346	8.395	9.444
.5	1.080	2.160	3.241	4.321	5.401	6.481	7.562	8.642	9.722
.6	1.111	2.222	3.333	4.444	5.556	6.667	7.778	8.889	10.000
.7	1.142	2.284	3.426	4.568	5.710	6.852	7.994	9.136	10.278
.8	1.173	2.346	3.519	4.691	5.864	7.037	8.210	9.383	10.556
.9	1.204	2.407	3.611	4.815	6.019	7.222	8.426	9.630	10.833
4.0	1.235	2.469	3.704	4.938	6.173	7.407	8.642	9.877	11.111
.1	1.265	2.531	3.796	5.062	6.327	7.593	8.858	10.123	11.389
.2	1.296	2.593	3.889	5.185	6.481	7.778	9.074	10.370	11.667
.3	1.327	2.654	3.981	5.309	6.636	7.963	9.290	10.617	11.944
.4	1.358	2.716	4.074	5.432	6.790	8.148	9.506	10.864	12.222
.5	1.389	2.778	4.167	5.556	6.944	8.333	9.722	11.111	12.500
.6	1.420	2.840	4.259	5.679	7.099	8.519	9.938	11.358	12.778
.7	1.451	2.901	4.352	5.802	7.253	8.704	10.154	11.605	13.056
.8	1.481	2.963	4.444	5.926	7.407	8.889	10.370	11.852	13.333
.9	1.512	3.025	4.537	6.049	7.562	9.074	10.586	12.099	13.611
5.0	1.543	3.086	4.630	6.173	7.716	9.259	10.802	12.346	13.889
.1	1.574	3.148	4.722	6.296	7.870	9.444	11.019	12.593	14.167
.2	1.605	3.210	4.815	6.420	8.025	9.630	11.235	12.840	14.444
.3	1.636	3.272	4.907	6.543	8.179	9.815	11.451	13.086	14.722
.4	1.667	3.333	5.000	6.667	8.333	10.000	11.667	13.333	15.000
.5	1.698	3.395	5.093	6.790	8.488	10.185	11.883	13.580	15.278
.6	1.728	3.457	5.185	6.914	8.642	10.370	12.099	13.827	15.556
.7	1.759	3.519	5.278	7.037	8.796	10.556	12.315	14.074	15.833
.8	1.790	3.580	5.370	7.160	8.951	10.741	12.531	14.321	16.111
.9	1.821	3.642	5.463	7.284	9.105	10.926	12.747	14.568	16.389
6.0	1.852	3.704	5.556	7.407	9.259	11.111	12.963	14.815	16.667

CU.YDS. PER 100 FT.

d-d'	1	2	3	4	5	6	7	8	9'
D-D'									
6.1	1.883	3.766	5.648	7.531	9.414	11.296	13.179	15.062	16.944
.2	1.914	3.827	5.741	7.654	9.568	11.481	13.395	15.309	17.222
.3	1.944	3.889	5.833	7.778	9.722	11.667	13.611	15.556	17.500
.4	1.975	3.951	5.926	7.901	9.877	11.852	13.827	15.802	17.778
.5	2.006	4.012	6.019	8.025	10.031	12.037	14.043	16.049	18.056
.6	2.037	4.074	6.111	8.148	10.185	12.222	14.259	16.296	18.333
.7	2.068	4.136	6.204	8.272	10.340	12.407	14.475	16.543	18.611
.8	2.099	4.198	6.296	8.395	10.494	12.593	14.691	16.790	18.889
.9	2.130	4.259	6.389	8.519	10.648	12.778	14.907	17.037	19.167
7.0	2.160	4.321	6.481	8.642	10.802	12.963	15.123	17.284	19.444
.1	2.191	4.383	6.574	8.766	10.957	13.148	15.340	17.531	19.722
.2	2.222	4.444	6.667	8.889	11.111	13.333	15.556	17.778	20.000
.3	2.253	4.506	6.759	9.012	11.265	13.519	15.772	18.025	20.278
.4	2.284	4.568	6.852	9.136	11.420	13.704	15.988	18.272	20.556
.5	2.315	4.630	6.944	9.259	11.574	13.889	16.204	18.519	20.833
.6	2.346	4.691	7.037	9.383	11.728	14.074	16.420	18.766	21.111
.7	2.377	4.753	7.130	9.506	11.883	14.259	16.636	19.012	21.389
.8	2.407	4.815	7.222	9.630	12.037	14.444	16.852	19.259	21.667
.9	2.438	4.877	7.315	9.753	12.191	14.630	17.067	19.506	21.944
8.0	2.469	4.938	7.407	9.877	12.346	14.815	17.284	19.753	22.222
.1	2.500	5.000	7.500	10.000	12.500	15.000	17.500	20.000	22.500
.2	2.531	5.062	7.593	10.123	12.654	15.185	17.716	20.247	22.778
.3	2.562	5.123	7.685	10.247	12.809	15.370	17.932	20.494	23.056
.4	2.593	5.185	7.778	10.370	12.963	15.556	18.148	20.741	23.333
.5	2.623	5.247	7.870	10.494	13.117	15.741	18.364	20.988	23.611
.6	2.654	5.309	7.963	10.617	13.272	15.926	18.580	21.235	23.889
.7	2.685	5.370	8.056	10.741	13.426	16.111	18.796	21.481	24.167
.8	2.716	5.432	8.148	10.864	13.580	16.296	19.012	21.728	24.444
.9	2.747	5.494	8.241	10.988	13.735	16.481	19.228	21.975	24.722
9.0	2.778	5.556	8.333	11.111	13.889	16.667	19.444	22.222	25.000
.1	2.809	5.617	8.426	11.235	14.043	16.852	19.660	22.469	25.278
.2	2.840	5.679	8.519	11.358	14.198	17.037	19.877	22.716	25.556
.3	2.870	5.741	8.611	11.481	14.352	17.222	20.093	22.963	25.833
.4	2.901	5.802	8.704	11.605	14.506	17.407	20.309	23.210	26.111
.5	2.932	5.864	8.796	11.728	14.660	17.593	20.525	23.457	26.389
.6	2.963	5.926	8.889	11.852	14.815	17.778	20.741	23.704	26.667
.7	2.994	5.988	8.981	11.975	14.969	17.963	20.957	23.951	26.944
.8	3.025	6.049	9.074	12.099	15.123	18.148	21.173	24.198	27.222
.9	3.056	6.111	9.167	12.222	15.278	18.333	21.389	24.444	27.500
10.0	3.086	6.173	9.259	12.346	15.432	18.519	21.605	24.691	27.778
.1	3.117	6.235	9.352	12.469	15.586	18.704	21.821	24.938	28.056
.2	3.148	6.296	9.444	12.593	15.741	18.889	22.037	25.185	28.333
.3	3.179	6.359	9.537	12.716	15.895	19.074	22.253	25.432	28.611
.4	3.210	6.420	9.630	12.840	16.049	19.259	22.469	25.679	28.889
.5	3.241	6.481	9.722	12.963	16.204	19.444	22.685	25.926	29.167
.6	3.272	6.543	9.815	13.086	16.359	19.630	22.901	26.173	29.444
.7	3.302	6.605	9.907	13.210	16.512	19.815	23.117	26.420	29.722
.8	3.333	6.667	10.000	13.333	16.667	20.000	23.333	26.667	30.000
.9	3.364	6.728	10.093	13.457	16.821	20.185	23.549	26.914	30.278
11.0	3.395	6.790	10.185	13.580	16.975	20.370	23.766	27.160	30.556
.1	3.426	6.852	10.278	13.704	17.130	20.556	23.981	27.407	30.833
.2	3.457	6.914	10.370	13.827	17.284	20.741	24.198	27.654	31.111
.3	3.488	6.975	10.463	13.951	17.438	20.926	24.414	27.901	31.389
.4	3.519	7.037	10.556	14.074	17.593	21.111	24.630	28.148	31.667
.5	3.549	7.099	10.648	14.198	17.747	21.296	24.846	28.395	31.944
.6	3.580	7.160	10.741	14.321	17.901	21.481	25.062	28.642	32.222
.7	3.611	7.222	10.833	14.444	18.056	21.667	25.278	28.889	32.500
.8	3.642	7.284	10.926	14.568	18.210	21.852	25.494	29.136	32.778
.9	3.673	7.346	11.019	14.691	18.364	22.037	25.710	29.383	33.056
12.0	3.704	7.407	11.111	14.815	18.519	22.222	25.926	29.630	33.333

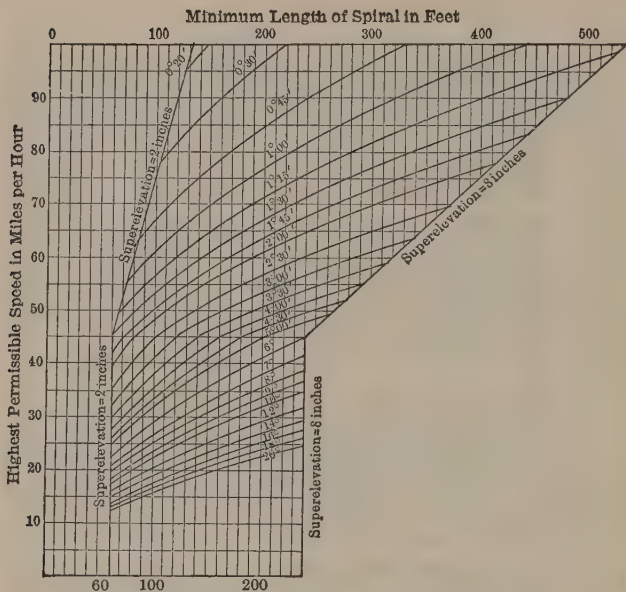
CU.YDS. PER 100 FT.

d-d'	1	2	3	4	5	6	7	8	9
D-D'									
12.1	3.735	7.469	11.204	14.938	18.673	22.407	26.142	29.877	33.611
.2	3.766	7.531	11.296	15.062	18.827	22.593	26.350	30.123	33.889
.3	3.796	7.593	11.389	15.185	18.981	22.778	26.574	30.370	34.167
.4	3.827	7.654	11.481	15.309	19.136	22.963	26.790	30.617	34.444
.5	3.858	7.716	11.574	15.432	19.290	23.148	27.006	30.864	34.722
.6	3.889	7.778	11.667	15.556	19.444	23.333	27.222	31.111	35.000
.7	3.920	7.840	11.759	15.679	19.599	23.519	27.438	31.359	35.278
.8	3.951	7.901	11.852	15.802	19.753	23.704	27.654	31.605	35.556
.9	3.981	7.963	11.944	15.926	19.907	23.889	27.870	31.852	35.833
13.0	4.012	8.025	12.037	16.049	20.062	24.074	28.086	32.099	36.111
.1	4.043	8.086	12.130	16.173	20.216	24.259	28.302	32.346	36.389
.2	4.074	8.148	12.222	16.296	20.370	24.444	28.519	32.593	36.667
.3	4.105	8.210	12.315	16.420	20.525	24.630	28.735	32.840	36.944
.4	4.136	8.272	12.407	16.543	20.679	24.815	28.951	33.086	37.222
.5	4.167	8.333	12.500	16.667	20.833	25.000	29.167	33.333	37.500
.6	4.198	8.395	12.593	16.790	20.988	25.185	29.383	33.580	37.778
.7	4.228	8.457	12.685	16.914	21.142	25.370	29.599	33.827	38.056
.8	4.259	8.519	12.778	17.037	21.296	25.556	29.815	34.074	38.333
.9	4.290	8.580	12.870	17.160	21.451	25.741	30.031	34.321	38.611
14.0	4.321	8.642	12.963	17.284	21.605	25.926	30.247	34.568	38.889
.1	4.352	8.704	13.056	17.407	21.759	26.111	30.463	34.815	39.167
.2	4.383	8.766	13.148	17.531	21.914	26.296	30.679	35.062	39.444
.3	4.414	8.827	13.241	17.654	22.068	26.481	30.895	35.309	39.722
.4	4.444	8.889	13.333	17.778	22.222	26.667	31.111	35.556	40.000
.5	4.475	8.951	13.426	17.901	22.377	26.852	31.327	35.802	40.278
.6	4.506	9.012	13.519	18.025	22.531	27.037	31.543	36.049	40.556
.7	4.537	9.074	13.611	18.148	22.685	27.222	31.759	36.296	40.833
.8	4.568	9.136	13.704	18.272	22.840	27.407	31.975	36.543	41.111
.9	4.599	9.198	13.796	18.395	22.994	27.593	32.191	36.790	41.389
15.0	4.630	9.259	13.889	18.519	23.148	27.778	32.407	37.037	41.667
.1	4.660	9.321	13.981	18.642	23.302	27.963	32.623	37.284	41.944
.2	4.691	9.383	14.074	18.766	23.457	28.148	32.840	37.531	42.222
.3	4.722	9.444	14.167	18.889	23.611	28.333	33.056	37.778	42.500
.4	4.753	9.506	14.259	19.012	23.766	28.519	33.272	38.025	42.778
.5	4.784	9.568	14.352	19.136	23.920	28.704	33.488	38.272	43.056
.6	4.815	9.630	14.444	19.259	24.074	28.889	33.704	38.519	43.333
.7	4.846	9.691	14.537	19.383	24.228	29.074	33.920	38.766	43.611
.8	4.877	9.753	14.630	19.506	24.383	29.259	34.136	39.012	43.889
.9	4.907	9.815	14.722	19.630	24.537	29.444	34.352	39.259	44.167
16.0	4.938	9.877	14.815	19.753	24.691	29.630	34.568	39.506	44.444
.1	4.969	9.938	14.907	19.877	24.846	29.815	34.784	39.753	44.722
.2	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000
.3	5.031	10.062	15.093	20.123	25.154	30.185	35.216	40.247	45.278
.4	5.062	10.123	15.185	20.247	25.309	30.370	35.432	40.494	45.556
.5	5.093	10.185	15.278	20.370	25.463	30.556	35.648	40.741	45.833
.6	5.123	10.247	15.370	20.494	25.617	30.741	35.864	40.988	46.111
.7	5.154	10.309	15.463	20.617	25.772	30.926	36.080	41.235	46.389
.8	5.185	10.370	15.556	20.741	25.926	31.111	36.296	41.481	46.667
.9	5.216	10.432	15.648	20.864	26.080	31.296	36.512	41.728	46.944
17.0	5.247	10.494	15.741	20.988	26.235	31.481	36.728	41.975	47.222
.1	5.278	10.556	15.833	21.111	26.389	31.667	36.944	42.222	47.500
.2	5.309	10.617	15.926	21.235	26.543	31.852	37.160	42.469	47.778
.3	5.340	10.679	16.019	21.358	26.698	32.037	37.377	42.716	48.056
.4	5.370	10.741	16.111	21.481	26.852	32.222	37.593	42.963	48.333
.5	5.401	10.802	16.204	21.605	27.006	32.407	37.809	43.210	48.611
.6	5.432	10.864	16.296	21.728	27.160	32.593	38.025	43.457	48.889
.7	5.463	10.926	16.389	21.852	27.315	32.778	38.241	43.704	49.167
.8	5.494	10.988	16.481	21.975	27.469	32.963	38.457	43.951	49.444
.9	5.525	11.049	16.574	22.099	27.623	33.148	38.673	44.198	49.722
18.0	5.556	11.111	16.667	22.222	27.778	33.333	38.889	44.444	50.000

d-d'	1	2	3	4	5	6	7	8	9
D-D'									
18.1	5.586	11.173	16.759	22.346	27.932	33.519	39.105	44.691	50.278
.2	5.617	11.235	16.852	22.469	28.086	33.704	39.321	44.938	50.556
.3	5.648	11.296	16.944	22.593	28.241	33.889	39.537	45.185	50.833
.4	5.679	11.358	17.037	22.716	28.395	34.074	39.753	45.432	51.111
.5	5.710	11.420	17.130	22.840	28.549	34.259	39.969	45.679	51.389
.6	5.741	11.481	17.222	22.963	28.704	34.444	40.185	45.926	51.667
.7	5.772	11.543	17.315	23.086	28.858	34.630	40.401	46.173	51.944
.8	5.802	11.605	17.407	23.210	29.012	34.815	40.617	46.420	52.222
.9	5.833	11.667	17.500	23.333	29.167	35.000	40.833	46.667	52.500
19.0	5.864	11.728	17.593	23.457	29.321	35.185	41.049	46.914	52.778
.1	5.895	11.790	17.685	23.580	29.475	35.370	41.265	47.160	53.056
.2	5.926	11.852	17.778	23.704	29.630	35.556	41.481	47.407	53.333
.3	5.957	11.914	17.870	23.827	29.784	35.741	41.698	47.654	53.611
.4	5.988	11.975	17.963	23.951	29.938	35.926	41.914	47.901	53.889
.5	6.019	12.037	18.056	24.074	30.093	36.111	42.130	48.148	54.167
.6	6.049	12.099	18.148	24.198	30.247	36.296	42.346	48.395	54.444
.7	6.080	12.160	18.241	24.321	30.401	36.481	42.562	48.642	54.722
.8	6.111	12.222	18.333	24.444	30.556	36.667	42.778	48.889	55.000
.9	6.142	12.284	18.426	24.568	30.710	36.852	42.994	49.136	55.278
20.0	6.173	12.346	18.519	24.691	30.864	37.037	43.210	49.383	55.556
.1	6.204	12.407	18.611	24.815	31.019	37.222	43.426	49.630	55.833
.2	6.235	12.469	18.704	24.938	31.173	37.407	43.642	49.877	56.111
.3	6.265	12.531	18.796	25.062	31.327	37.593	43.858	50.123	56.389
.4	6.296	12.593	18.889	25.185	31.481	37.778	44.074	50.370	56.667
.5	6.327	12.654	18.981	25.309	31.636	37.963	44.290	50.617	56.944
.6	6.359	12.716	19.074	25.432	31.790	38.148	44.506	50.864	57.222
.7	6.389	12.778	19.167	25.556	31.944	38.333	44.722	51.111	57.500
.8	6.420	12.840	19.259	25.679	32.099	38.519	44.938	51.359	57.778
.9	6.451	12.901	19.352	25.802	32.253	38.704	45.154	51.605	58.056
21.0	6.481	12.963	19.444	25.926	32.407	38.889	45.370	51.852	58.333
.1	6.512	13.025	19.537	26.049	32.562	39.074	45.586	52.099	58.611
.2	6.543	13.086	19.630	26.173	32.716	39.259	45.802	52.346	58.889
.3	6.574	13.148	19.722	26.296	32.870	39.444	46.019	52.593	59.167
.4	6.605	13.210	19.815	26.420	33.025	39.630	46.235	52.840	59.444
.5	6.636	13.272	19.907	26.543	33.179	39.815	46.451	53.086	59.722
.6	6.667	13.333	20.000	26.667	33.333	40.000	46.667	53.333	60.000
.7	6.698	13.396	20.093	26.790	33.488	40.185	46.883	53.580	60.278
.8	6.728	13.457	20.185	26.914	33.642	40.370	47.099	53.827	60.556
.9	6.759	13.519	20.278	27.037	33.796	40.556	47.315	54.074	60.833
22.0	6.790	13.580	20.370	27.160	33.951	40.741	47.531	54.321	61.111
.1	6.821	13.641	20.463	27.284	34.105	40.926	47.747	54.568	61.389
.2	6.852	13.704	20.556	27.407	34.259	41.111	47.963	54.815	61.667
.3	6.883	13.766	20.648	27.531	34.414	41.296	48.179	55.062	61.944
.4	6.914	13.827	20.741	27.654	34.568	41.481	48.395	55.309	62.222
.5	6.944	13.889	20.833	27.778	34.722	41.667	48.611	55.556	62.500
.6	6.975	13.951	20.926	27.901	34.877	41.852	48.827	55.802	62.778
.7	7.006	14.012	21.019	28.025	35.031	42.037	49.043	56.049	63.056
.8	7.037	14.074	21.111	28.148	35.185	42.222	49.259	56.296	63.333
.9	7.068	14.136	21.204	28.272	35.340	42.407	49.475	56.543	63.611
23.0	7.099	14.198	21.296	28.395	35.494	42.593	49.691	56.790	63.889
.1	7.130	14.259	21.389	28.519	35.648	42.778	49.907	57.037	64.167
.2	7.160	14.321	21.481	28.642	35.802	42.963	50.123	57.284	64.444
.3	7.191	14.383	21.574	28.766	35.957	43.148	50.340	57.531	64.722
.4	7.222	14.444	21.667	28.889	36.111	43.333	50.556	57.778	65.000
.5	7.253	14.506	21.759	29.012	36.265	43.519	50.772	58.025	65.278
.6	7.284	14.568	21.852	29.136	36.420	43.704	50.988	58.272	65.556
.7	7.315	14.630	21.944	29.259	36.574	43.889	51.204	58.519	65.833
.8	7.346	14.691	22.037	29.383	36.728	44.074	51.420	58.766	66.111
.9	7.377	14.753	22.130	29.506	36.883	44.259	51.636	59.012	66.389
24.0	7.407	14.815	22.222	29.630	37.037	44.444	51.852	59.259	66.667

CU.YDS. PER 100 FT.

d-d'	1	2	3	4	5	6	7	8	9
D-D'									
24.1	7.438	14.877	22.315	29.753	37.191	44.630	52.068	59.506	66.944
.2	7.469	14.938	22.407	29.877	37.346	44.815	52.284	59.753	67.222
.3	7.500	15.000	22.500	30.000	37.500	45.000	52.500	60.000	67.500
.4	7.531	15.062	22.593	30.123	37.654	45.185	52.716	60.247	67.778
.5	7.562	15.123	22.685	30.247	37.809	45.370	52.932	60.494	68.056
.6	7.593	15.185	22.778	30.370	37.963	45.556	53.148	60.741	68.333
.7	7.623	15.247	22.870	30.494	38.117	45.741	53.364	60.988	68.611
.8	7.654	15.309	22.963	30.617	38.272	45.926	53.580	61.235	68.889
.9	7.685	15.370	23.056	30.741	38.426	46.111	53.796	61.481	69.167
25.0	7.716	15.432	23.148	30.864	38.580	46.296	54.012	61.728	69.444
.1	7.747	15.494	23.241	30.988	38.735	46.481	54.228	61.975	69.722
.2	7.778	15.556	23.333	31.111	38.889	46.667	54.444	62.222	70.000
.3	7.809	15.617	23.426	31.235	39.043	46.852	54.660	62.469	70.278
.4	7.840	15.679	23.519	31.358	39.198	47.037	54.877	62.716	70.556
.5	7.870	15.741	23.611	31.481	39.352	47.222	55.093	62.963	70.833
.6	7.901	15.802	23.704	31.605	39.506	47.407	55.309	63.210	71.111
.7	7.932	15.864	23.796	31.728	39.660	47.593	55.525	63.457	71.389
.8	7.963	15.926	23.889	31.852	39.815	47.778	55.741	63.704	71.667
.9	7.994	15.988	23.981	31.975	39.969	47.963	55.957	63.951	71.944
26.0	8.025	16.049	24.074	32.099	40.123	48.148	56.173	64.198	72.222
.1	8.056	16.111	24.167	32.222	40.278	48.333	56.389	64.444	72.500
.2	8.086	16.173	24.259	32.346	40.432	48.519	56.605	64.691	72.778
.3	8.117	16.235	24.352	32.469	40.586	48.704	56.821	64.938	73.056
.4	8.148	16.296	24.444	32.593	40.741	48.889	57.037	65.185	73.333
.5	8.179	16.358	24.537	32.716	40.895	49.074	57.253	65.432	73.611
.6	8.210	16.420	24.630	32.840	41.049	49.259	57.469	65.679	73.889
.7	8.241	16.481	24.722	32.963	41.204	49.444	57.685	65.926	74.167
.8	8.272	16.543	24.815	33.086	41.359	49.630	57.901	66.173	74.444
.9	8.302	16.605	24.907	33.210	41.512	49.815	58.117	66.420	74.722
27.0	8.333	16.667	25.000	33.333	41.667	50.000	58.333	66.667	75.000
.1	8.364	16.728	25.093	33.457	41.821	50.185	58.549	66.914	75.278
.2	8.395	16.790	25.185	33.580	41.975	50.370	58.766	67.160	75.556
.3	8.426	16.852	25.278	33.704	42.130	50.556	58.981	67.407	75.833
.4	8.457	16.914	25.370	33.827	42.284	50.741	59.198	67.654	76.111
.5	8.488	16.975	25.463	33.951	42.438	50.926	59.414	67.901	76.389
.6	8.519	17.037	25.556	34.074	42.593	51.111	59.630	68.148	76.667
.7	8.549	17.099	25.648	34.198	42.747	51.296	59.846	68.395	76.944
.8	8.580	17.160	25.741	34.321	42.901	51.481	60.062	68.642	77.222
.9	8.611	17.222	25.833	34.444	43.056	51.667	60.278	68.889	77.500
28.0	8.642	17.284	25.926	34.568	43.210	51.852	60.494	69.136	77.778
.1	8.673	17.346	26.019	34.691	43.364	52.037	60.710	69.383	78.056
.2	8.704	17.407	26.111	34.815	43.519	52.222	60.926	69.630	78.333
.3	8.735	17.469	26.204	34.938	43.673	52.407	61.142	69.877	78.611
.4	8.766	17.531	26.296	35.062	43.827	52.593	61.359	70.123	78.889
.5	8.796	17.593	26.389	35.185	43.981	52.778	61.574	70.370	79.167
.6	8.827	17.654	26.481	35.309	44.136	52.963	61.790	70.617	79.444
.7	8.858	17.716	26.574	35.432	44.290	53.148	62.006	70.864	79.722
.8	8.889	17.778	26.667	35.556	44.444	53.333	62.222	71.111	80.000
.9	8.920	17.840	26.759	35.679	44.599	53.519	62.438	71.359	80.278
29.0	8.951	17.901	26.852	35.802	44.753	53.704	62.654	71.605	80.556
.1	8.981	17.963	26.944	35.926	44.907	53.889	62.870	71.852	80.833
.2	9.012	18.025	27.037	36.049	45.062	54.074	63.086	72.099	81.111
.3	9.043	18.086	27.130	36.173	45.216	54.259	63.302	72.346	81.389
.4	9.074	18.148	27.222	36.296	45.370	54.444	63.519	72.593	81.667
.5	9.105	18.210	27.315	36.420	45.525	54.630	63.735	72.840	81.944
.6	9.136	18.272	27.407	36.543	45.679	54.815	63.951	73.086	82.222
.7	9.167	18.333	27.500	36.667	45.833	55.000	64.167	73.333	82.500
.8	9.198	18.395	27.593	36.790	45.988	55.185	64.383	73.580	82.778
.9	9.228	18.457	27.685	36.914	46.142	55.370	64.599	73.827	83.056
30.0	9.259	18.519	27.778	37.037	46.296	55.556	64.815	74.074	83.333



Limiting curves. For all curves which are liable to limit the speed of trains, the length of spiral should equal that indicated on the line marked "Superelevation = 8 in." Longer spirals may be used provided the increased length does not adversely affect the degree of curve or seriously affect the cost of construction.

Minor curves. For minor curves the length of spiral should never be less than that indicated by the diagram; an increase of about 50 per cent over the indicated length may be desirable where cost is not seriously affected.

Spirals need not be used when superelevation required for highest permissible speed is less than 2 in.

TABLE XXXIV.—ELEMENTS OF THE SPIRAL OF 297
CHORD-LENGTH, 100

n	Degree of Curve. D_s	Spiral Angle. s	Inclination of Chord to Axis of Y.	Latitude of Each Chord. $100 \times \cos \text{Incl.}$	Sum of the Latitudes. y
0	0° 00'	0° 00'	0° 00'		
1	10	10	05	99.99989423	99.99989423
2	20	30	20	99.99830769	199.99820192
3	30	1	45	99.99143275	299.98963467
4	40	1 40	1 20	99.97292412	399.96255879
5	50	2 30	2 05	99.93390007	499.89645886
6	1	3 30	3	99.8629535	599.7594123
7	1 10	4 40	4 05	99.7461539	699.5055662
8	1 20	6	5 20	99.5670790	799.0726452
9	1 30	7 30	6 45	99.3068457	898.3794909
10	1 40	9 10	8 20	98.944164	997.3236549
11	1 50	11	10 05	98.455415	1095.779070
12	2	13	12	97.814760	1193.593830
13	2 10	15 10	14 05	96.994284	1290.588114
14	2 20	17 30	16 20	95.964184	1386.552298
15	2 30	20	18 45	94.693014	1481.245312
16	2 40	22 40	21 20	93.147975	1574.393287
17	2 50	25 30	24 05	91.295292	1665.685579
18	3	28 30	27	89.100650	1754.789229
19	3 10	31 40	30 05	86.529730	1841.318959
20	3 20	35	33 20	83.548780	1924.867739

n	Departure of Each Chord. $100 \times \sin \text{Incl.}$	Sum of the Departures. x	Logarithm. $\log y$	Logarithm. $\log x$
1	.1454441	.1454441	1.9999995	9.1626960
2	.5817731	.7272172	2.3010261	9.8616641
3	1.3089593	2.0361765	2.4771063	0.3088154
4	2.3263960	4.3630725	2.6020194	0.6397924
5	3.6353009	7.9983734	2.6988800	0.9030017
6	5.233596	13.231969	2.7779771	1.1216244
7	7.120730	20.352699	2.8447911	1.3086220
8	9.294991	29.647690	2.9025862	1.4719909
9	11.75374	41.40143	2.9534598	1.6170153
10	14.49319	55.89462	2.9988361	1.7473701
11	17.50803	73.40265	3.0397231	1.8657117
12	20.79117	94.19382	3.0768567	1.9740224
13	24.33329	118.52711	3.1107877	2.0738177
14	28.12251	146.64962	3.1419362	2.1662811
15	32.14395	178.79357	3.1706269	2.2523519
16	36.37932	215.17289	3.1971131	2.3327875
17	40.80649	255.97938	3.2215938	2.4082049
18	45.39905	301.37843	3.2442250	2.4791121
19	50.12591	351.50434	3.2651291	2.5459307
20	54.95090	406.45524	3.2844009	2.6090128

n	$\log \frac{x}{y} =$ $\log \tan i$	Deflection Angle. i	R_s	n	$\log \frac{x}{y} =$ $\log \tan i$	Deflection Angle. i	R_s
1	7.1626964	0° 05' 00." 00	34377.5	11	8.8259886	3° 49' 56." 39	3125.36
2	7.5606380	0° 12' 30." 00	17188.8	12	8.8971657	4° 30' 43." 95	2864.93
3	7.8317091	0° 23' 20." 00	11459.2	13	8.9630300	5° 14' 50." 28	2644.58
4	8.0377730	0° 37' 29." 99	8594.42	14	9.0243449	6° 02' 14." 93	2455.70
5	8.2041217	0° 54' 59." 97	6875.55	15	9.0817250	6° 52' 57." 31	2292.01
6	8.3436473	1° 15' 49." 90	5729.65	16	9.1356744	7° 46' 56." 71	2148.79
7	8.4638309	1° 39' 59." 75	4911.15	17	9.1866111	8° 44' 12." 26	2022.41
8	8.5694047	2° 07' 29." 45	4297.28	18	9.2348871	9° 44' 42." 92	1910.08
9	8.6635555	2° 38' 18." 90	3819.83	19	9.2808016	10° 48' 27." 44	1809.57
10	8.7485340	3° 12' 27." 95	3437.87	20	9.3246119	11° 55' 24." 34	1719.12

Rule for Finding a Deflection

Read under the *heading* corresponding to the point at which the instrument stands, and on the *line* of the number of the point observed.

<i>n</i>	Inst. at S <i>i</i>	Inst. at 1 <i>i</i>	Inst. at 2 <i>i</i>	Inst. at 3 <i>i</i>	Inst. at 4 <i>i</i>	<i>n</i>
0	00'	05'	17' 30''	36' 40''	1° 02' 30''	0
1	05	00	10	27 30	51 40	1
2	12 30''	10	00	15	37 30	2
3	23 20	22 30''	15	00	20	3
4	37 30	38 20	32 30	20	00	4
5	55 00	57 30	53 20	42 30	25	5
6	1° 15 50	1° 20 00	1° 17 30	1° 08 20	52 30	6
7	1 40 00	1 45 50	1 45 00	1 37 30	1 23 20	7
8	2 07 29	2 15 00	2 15 50	2 10 00	1 57 30	8
9	2 38 19	2 47 29	2 49 59	2 45 50	2 35 00	9
10	3 12 28	3 23 18	3 27 29	3 24 59	3 15 50	10
11	3 49 56	4 02 27	4 08 18	4 07 28	3 59 59	11
12	4 30 44	4 44 55	4 52 26	4 53 17	4 47 28	12
13	5 14 50	5 30 42	5 39 54	5 42 25	5 38 16	13
14	6 02 15	6 19 47	6 30 40	6 34 52	6 32 24	14
15	6 52 57	7 12 11	7 24 44	7 30 37	7 29 50	15
16	7 46 57	8 07 51	8 22 06	8 29 40	8 30 34	16
17	8 44 12	9 06 49	9 22 45	9 32 01	9 34 36	17
18	9 44 43	10 09 01	10 26 39	10 37 37	10 41 55	18
19	10 48 27	11 14 28	11 33 49	11 46 29	11 52 29	19
20	11 55 24	12 23 08	12 44 12	12 58 35	13 06 18	20

<i>n</i>	Inst. at 5 <i>i</i>	Inst. at 6 <i>i</i>	Inst. at 7 <i>i</i>	Inst. at 8 <i>i</i>	Inst. at 9 <i>i</i>	<i>n</i>
0	1° 35' 00''	2° 14' 10''	3° 00' 00''	3° 52' 31''	4° 51' 41''	0
1	1 22 30	2 00 00	2 44 10	3 35 00	4 32 31	1
2	1 06 40	1 42 30	2 25 00	3 14 10	4 10 01	2
3	47 30	1 21 40	2 02 30	2 50 00	3 44 10	3
4	25	57 30	1 36 40	2 22 30	3 15 00	4
5	00	30	1 07 30	1 51 40	2 42 30	5
6	30	00	35	1 17 30	2 06 40	6
7	1 02 30	35	00	40	1 27 30	7
8	1 38 20	1 12 30	40	00	45	8
9	2 17 30	1 53 20	1 22 30	45	00	9
10	3 00 00	2 37 30	2 08 20	1 32 30	50	10
11	3 45 50	3 25 00	2 57 30	2 23 20	1 42 30	11
12	4 34 59	4 15 49	3 50 00	3 17 30	2 38 20	12
13	5 27 28	5 09 58	4 45 49	4 15 00	3 37 30	13
14	6 23 15	6 07 27	5 44 58	5 15 49	4 40 00	14
15	7 22 23	7 08 15	6 47 26	6 19 58	5 45 49	15
16	8 24 48	8 12 21	7 53 14	7 27 26	6 54 57	16
17	9 30 31	9 19 46	9 02 19	8 38 13	8 07 25	17
18	10 39 32	10 30 28	10 14 43	9 52 18	9 23 11	18
19	11 51 48	11 44 27	11 30 24	11 09 40	10 42 16	19
20	13 07 20	13 01 41	12 49 21	12 30 20	12 04 38	20

Rule for Finding a Deflection

Read under the *heading* corresponding to the point at which the instrument stands, and on the *line* of the number of the point observed.

<i>n</i>	Inst. at 10 <i>i</i>	Inst. at 11 <i>i</i>	Inst. at 12 <i>i</i>	Inst. at 13 <i>i</i>	Inst. at 14 <i>i</i>	Inst. at 15 <i>i</i>	<i>n</i>
0	5° 57' 32"	7° 10' 04"	8° 29' 16"	9° 55' 10"	11° 27' 45"	13° 07' 03"	0
1	5 36 42	6 47 33	8 05 05	9 29 18	11 00 13	12 37 49	1
2	5 12 31	6 21 42	7 37 34	9 00 06	10 29 20	12 05 16	2
3	4 45 01	5 52 32	7 06 43	8 27 35	9 55 08	11 29 23	3
4	4 14 10	5 20 01	6 32 32	7 51 44	9 17 36	10 50 10	4
5	3 40 00	4 44 10	5 55 01	7 12 32	8 36 45	10 07 37	5
6	3 02 30	4 05 00	5 14 11	6 30 02	7 52 33	9 21 45	6
7	2 21 40	3 22 30	4 30 00	5 44 11	7 05 02	8 32 34	7
8	1 37 30	2 36 40	3 42 30	4 55 00	6 14 11	7 40 02	8
9	50	1 47 30	2 51 40	4 02 30	5 20 00	6 44 11	9
10	00	55	1 57 30	3 06 40	4 22 30	5 45 01	10
11	55	00	1 00 00	2 07 30	3 21 40	4 42 30	11
12	1 52 30	1 00 00	00	1 05 00	2 17 30	3 36 40	12
13	2 53 20	2 02 30	1 05 00	00	1 10 00	2 27 30	13
14	3 57 30	3 08 20	2 12 30	1 10 00	00	1 15 00	14
15	5 05 00	4 17 30	3 23 20	2 22 30	1 15 00	00	15
16	6 15 49	5 29 59	4 37 30	3 38 20	2 32 30	1 20 00	16
17	7 29 57	6 45 48	5 54 59	4 57 30	3 53 20	2 42 30	17
18	8 47 24	8 04 57	7 15 48	6 19 59	5 17 30	4 08 20	18
19	10 08 10	9 27 24	8 39 56	7 45 48	6 44 59	5 37 30	19
20	11 32 14	10 53 09	10 07 23	9 14 56	8 15 48	7 09 59	20

<i>n</i>	Inst. at 16 <i>i</i>	Inst. at 17 <i>i</i>	Inst. at 18 <i>i</i>	Inst. at 19 <i>i</i>	Inst. at 20 <i>i</i>	<i>n</i>
0	14° 53' 03"	16° 45' 48"	18° 45' 17"	20° 51' 33"	23° 04' 36"	0
1	14 22 09	16 13 11	18 10 59	20 15 32	22 26 52	1
2	13 47 54	15 37 15	17 33 21	19 36 11	21 45 48	2
3	13 10 20	14 57 59	16 52 23	18 53 31	21 01 25	3
4	12 29 26	14 15 24	16 08 05	18 07 31	20 13 42	4
5	11 45 12	13 29 29	15 20 28	17 18 12	19 22 40	5
6	10 57 39	12 40 14	14 29 32	16 25 33	18 28 19	6
7	10 06 46	11 47 41	13 35 17	15 29 36	17 30 39	7
8	9 12 34	10 51 47	12 37 42	14 30 20	16 29 40	8
9	8 15 03	9 52 35	11 36 49	13 27 44	15 25 23	9
10	7 14 11	8 50 03	10 32 36	12 21 50	14 17 46	10
11	6 10 01	7 44 12	9 25 03	11 12 36	13 06 51	11
12	5 02 30	6 35 01	8 14 12	10 00 04	11 52 37	12
13	3 51 40	5 22 30	7 00 01	8 44 12	10 35 04	13
14	2 37 30	4 06 40	5 42 30	7 25 01	9 14 12	14
15	1 20 00	2 47 30	4 21 40	6 02 30	7 50 01	15
16	00	1 25 00	2 57 30	4 36 40	6 22 30	16
17	1 25 00	00	1 30 00	3 07 30	4 51 40	17
18	2 52 30	1 30 00	00	1 35	3 17 30	18
19	4 23 20	3 02 30	1 35 00	00	1 40	19
20	5 57 30	4 38 20	3 12 30	1 40	00	20

DEGREE OF CURVE AND VALUES OF THE COORDINATES x AND y , FOR EACH
CHORD-POINT OF THE SPIRAL FOR VARIOUS LENGTHS OF THE CHORD
CHORD-LENGTH = 10

n	nc	D_c	y	x	Log x
1	10	1° 40' 00"	10.000	0.0145	8.162696
2	20	3 20 02	20.000	.0727	8.861664
3	30	5 00 06	29.999	.2036	9.308815
4	40	6 40 13	39.996	.4363	9.639792
5	50	8 20 26	49.990	.7998	9.903002
6	60	10 00 45	59.976	1.323	0.121624
7	70	11 41 12	69.951	2.035	0.308622
8	80	13 21 48	79.907	2.965	0.471991
9	90	15 02 34	89.838	4.140	0.617015
10	100	16 43 31	99.732	5.589	0.747370
11	110	18 24 42	109.578	7.340	0.865712
12	120	20 06 07	119.359	9.419	0.974022
13	130	21 47 48	129.059	11.853	1.073818
14	140	23 29 46	138.655	14.655	1.166281
15	150	25 12 02	148.125	17.879	1.252352
16	160	26 54 39	157.439	21.517	1.332788
17	170	28 37 38	166.569	25.598	1.408205
18	180	30 21 01	175.479	30.138	1.479112
19	190	32 04 48	184.132	35.150	1.545931
20	200	33 49 02	192.487	40.646	1.609013
		35 33 46			

c. CHORD-LENGTH = 11

n	nc	D_s	y	x	Log x
1	11	1° 30' 55"	11.000	0.0160	8.204089
2	22	3 01 50	22.000	.0800	8.903057
3	33	4 32 48	32.999	.2240	9.350208
4	44	6 03 48	43.996	.4799	9.681185
5	55	7 34 52	54.989	.8798	9.944394
6	66	9 06 01	65.974	1.456	0.163017
7	77	10 37 16	76.946	2.239	0.350015
8	88	12 08 37	87.898	3.261	0.513384
9	99	13 40 06	98.822	4.554	0.658408
10	110	15 11 44	109.706	6.148	0.788763
11	121	16 43 31	120.536	8.074	0.907104
12	132	18 15 29	131.295	10.361	1.015415
13	143	19 47 39	141.965	13.038	1.115210
14	154	21 20 01	152.521	16.131	1.207674
15	165	22 52 38	162.937	19.667	1.293745
16	176	24 25 29	173.183	23.669	1.374180
17	187	25 58 36	183.226	28.158	1.449598
18	198	27 32 01	193.027	33.152	1.520505
19	209	29 05 45	202.545	38.665	1.587323
20	220	30 39 48	211.735	44.710	1.650405
		32 14 11			

c. CHORD-LENGTH = 12

n	nc	D_s	y	x	Log x
1	12	1° 23' 20"	12.000	0.0175	8.241877
2	24	2 46 41	24.000	.0873	8.940845
3	36	4 10 03	35.999	.2443	9.387997
4	48	5 33 28	47.996	.5236	9.718974
5	60	6 56 55	59.988	.9598	9.982183
6	72	8 20 26	71.971	1.588	0.200806
7	84	9 44 01	83.941	2.442	0.387803
8	96	11 07 42	95.889	3.558	0.551172
9	108	12 31 28	107.806	4.968	0.696196
10	120	13 55 21	119.679	6.707	0.826551
11	132	15 19 22	131.493	8.808	0.944893
12	144	16 43 31	143.231	11.303	1.053204
13	156	18 07 48	154.871	14.223	1.152999
14	168	19 32 15	166.886	17.598	1.245462
15	180	20 56 53	177.749	21.455	1.331533
16	192	22 21 43	188.927	25.821	1.411969
17	204	23 46 44	199.883	30.718	1.487386
18	216	25 11 59	210.575	36.165	1.558293
19	228	26 37 28	220.958	42.181	1.625113
20	240	28 03 12	230.984	48.774	1.688194
		29 29 12			

c. CHORD-LENGTH = 13

n	nc	D_s	y	x	Log x
1	13	1° 16' 55"	13.000	0.0189	8.276639
2	26	2 33 52	26.000	.0945	8.975607
3	39	3 50 49	38.999	.2647	9.422759
4	52	5 07 48	51.995	.5672	9.753736
5	65	6 24 49	64.987	1.040	0.016945
6	78	7 41 53	77.969	1.720	0.235568
7	91	8 59 00	90.936	2.646	0.422565
8	104	10 16 12	103.879	3.854	0.585934
9	117	11 33 28	116.789	5.382	0.730959
10	130	12 50 49	129.652	7.266	0.861313
11	143	14 08 16	142.451	9.542	0.979655
12	156	15 25 50	155.167	12.245	1.087966
13	169	16 43 30	167.776	15.409	1.187761
14	182	18 01 18	180.252	19.064	1.280224
15	195	19 19 14	192.562	23.243	1.366295
16	208	20 37 20	204.671	27.972	1.446731
17	221	21 55 34	216.540	33.277	1.522148
18	234	23 14 00	228.123	39.179	1.593055
19	247	24 32 35	239.371	45.696	1.659874
20	260	25 51 23	250.233	52.839	1.722956
		27 10 23			

c. CHORD-LENGTH = 14

n	nc	D_s	y	x	Log x
1	14	1° 11' 26"	14.000	0.0204	8.308824
2	28	2 22 52	28.000	.1018	9.007792
3	42	3 34 19	41.999	.2851	9.454943
4	56	4 45 48	55.995	.6108	9.785920
5	70	5 57 18	69.986	1.120	0.049130
6	84	7 08 51	83.966	1.852	0.267752
7	98	8 20 26	97.931	2.849	0.454750
8	112	9 32 04	111.870	4.151	0.618119
9	126	10 43 47	125.773	5.796	0.763143
10	140	11 55 33	139.625	7.825	0.893498
11	154	13 07 24	153.409	10.276	1.011840
12	168	14 19 20	167.103	13.187	1.120150
13	182	15 31 22	180.682	16.594	1.219946
14	196	16 43 29	194.117	20.531	1.312409
15	210	17 55 44	207.374	25.031	1.398480
16	224	19 06 05	220.415	30.124	1.478915
17	238	20 20 34	233.196	35.837	1.554333
18	252	21 33 11	245.670	42.193	1.625240
19	266	22 45 56	257.785	49.211	1.692059
20	280	23 58 51	269.481	56.903	1.755141
		25 11 55			

c. CHORD-LENGTH = 15

n	nc	D_s	y	x	Log x
1	15	1° 06' 40"	15.000	0.0218	8.338787
2	30	2 13 20	30.000	.1091	9.037755
3	45	3 20 02	44.998	.3054	9.484907
4	60	4 26 44	59.994	.6545	9.815884
5	75	5 33 28	74.984	1.200	0.079093
6	90	6 40 13	89.964	1.985	0.297716
7	105	7 47 01	104.926	3.053	0.484713
8	120	8 53 51	119.861	4.447	0.648082
9	135	10 00 45	134.757	6.210	0.793107
10	150	11 07 41	149.599	8.384	0.923461
11	165	12 14 41	164.367	11.010	1.041803
12	180	13 21 47	179.039	14.129	1.150114
13	195	14 28 56	193.588	17.779	1.249909
14	210	15 36 09	207.983	21.997	1.342372
15	225	16 43 28	222.187	26.819	1.428443
16	240	17 50 54	236.159	32.276	1.508879
17	255	18 58 25	249.853	38.397	1.584296
18	270	20 06 02	263.218	45.207	1.655203
19	285	21 13 47	276.198	52.726	1.722022
20	300	22 21 39	288.730	60.968	1.785104
		23 29 48			

c. CHORD-LENGTH = 16

n	nc	D_s	y	x	$\text{Log } x$
1	16	1° 02' 30"	16.000	0.0233	8.366816
2	32	2 05 00	32.000	.1164	9.065784
3	48	3 07 31	47.998	.3258	9.512935
4	64	4 10 03	63.994	.6981	9.843912
5	80	5 12 36	79.983	1.280	0.107122
6	96	6 15 11	95.961	2.117	0.325744
7	112	7 17 47	111.921	3.256	0.512742
8	128	8 20 26	127.852	4.744	0.676111
9	144	9 23 07	143.741	6.624	0.821135
10	160	10 25 51	159.572	8.943	0.951490
11	176	11 28 37	175.325	11.744	1.069832
12	192	12 31 28	190.975	15.071	1.178142
13	208	13 34 21	206.494	18.964	1.277938
14	224	14 37 20	221.848	23.464	1.370401
15	240	15 40 21	236.999	28.607	1.456472
16	256	16 43 28	251.903	34.428	1.536907
17	272	17 46 40	266.510	40.957	1.612325
18	288	18 49 57	280.766	48.221	1.683232
19	304	19 53 20	294.611	56.241	1.750051
20	320	20 56 49	307.979	65.032	1.813133
		22 00 23			

c. CHORD-LENGTH = 17

n	nc	D_s	y	x	$\text{Log } x$
1	17	0° 58' 49"	17.000	0.0247	8.393145
2	34	1 57 38	34.000	.1236	9.092113
3	51	2 56 27	50.998	.3461	9.539264
4	68	3 55 19	67.994	.7417	9.870241
5	85	4 54 12	84.982	1.360	0.133451
6	102	5 53 06	101.959	2.249	0.352073
7	119	6 52 00	118.916	3.460	0.539071
8	136	7 50 57	135.842	5.040	0.702440
9	153	8 49 55	152.725	7.038	0.847464
10	170	9 48 56	169.545	9.502	0.977819
11	187	10 48 00	186.282	12.478	1.096161
12	204	11 47 07	202.911	16.013	1.204471
13	221	12 46 15	219.400	20.150	1.304267
14	238	13 45 27	235.714	24.930	1.396750
15	255	14 44 44	251.812	30.395	1.482801
16	272	15 44 03	267.647	36.579	1.563236
17	289	16 43 27	283.167	43.516	1.638654
18	306	17 42 56	298.314	51.234	1.709561
19	323	18 42 29	313.024	59.756	1.776880
20	340	19 42 07	327.228	69.097	1.839462
		20 41 49			

c. CHORD-LENGTH = 18

<i>n</i>	<i>nc</i>	<i>D_s</i>	<i>y</i>	<i>x</i>	Log <i>x</i>
1	18	0° 55' 33"	18.000	0.0262	8.417968
2	36	1 51 07	36.000	.1309	9.116937
3	54	2 46 40	53.998	.3665	9.564088
4	72	3 42 16	71.993	.7853	9.895065
5	90	4 37 51	89.981	1.440	0.158274
6	108	5 33 23	107.957	2.382	0.376897
7	126	6 29 05	125.911	3.663	0.563894
8	144	7 24 45	143.833	5.337	0.727263
9	162	8 20 26	161.708	7.452	0.872288
10	180	9 16 08	179.518	10.061	1.002643
11	198	10 11 54	197.240	13.212	1.120984
12	216	11 07 41	214.847	16.955	1.229295
13	234	12 03 31	232.306	21.335	1.329090
14	252	12 59 24	249.579	26.397	1.421554
15	270	13 55 20	266.624	32.183	1.507624
16	288	14 51 18	283.391	38.731	1.588060
17	306	15 47 20	299.824	46.076	1.663477
18	324	16 43 27	315.862	54.248	1.734385
19	342	17 39 37	331.437	63.271	1.801203
20	360	18 35 51	346.476	73.161	1.864285
		19 32 08			

c. CHORD-LENGTH = 19

<i>n</i>	<i>nc</i>	<i>D_s</i>	<i>y</i>	<i>x</i>	Log <i>x</i>
1	19	0° 52' 38"	19.000	0.0276	8.441450
2	38	1 45 16	38.000	.1382	9.140418
3	57	2 37 54	56.998	.3869	9.587569
4	76	3 30 34	75.993	.8290	9.918546
5	95	4 23 13	94.980	1.520	0.181755
6	114	5 15 54	113.954	2.514	0.400378
7	133	6 08 36	132.906	3.867	0.587376
8	152	7 01 19	151.824	5.633	0.750744
9	171	7 54 03	170.692	7.866	0.895769
10	190	8 46 49	189.491	10.620	1.026124
11	209	9 39 36	208.198	13.947	1.144465
12	228	10 32 26	226.783	17.897	1.252776
13	247	11 25 18	245.212	22.520	1.352571
14	266	12 18 12	263.445	27.863	1.445035
15	285	13 11 09	281.437	33.971	1.531105
16	304	14 04 09	299.135	40.883	1.611541
17	323	14 57 11	316.481	48.636	1.686958
18	342	15 50 16	333.410	57.262	1.757866
19	361	16 43 25	349.851	66.786	1.824684
20	380	17 36 38	365.725	77.226	1.887766
		18 29 54			

c. CHORD-LENGTH = 20

n	nc	D_s	y	x	Log x
1	20	0° 50' 00"	20.000	0.0291	8.463726
2	40	1 40 00	40.000	.1454	9.162694
3	60	2 30 01	59.998	.4072	9.609845
4	80	3 20 02	79.993	.8726	9.940822
5	100	4 10 03	99.979	1.600	0.204032
6	120	5 00 05	119.952	2.646	0.422654
7	140	5 50 08	139.901	4.071	0.609652
8	160	6 40 13	159.815	5.930	0.773021
9	180	7 30 18	179.676	8.280	0.918045
10	200	8 20 26	199.465	11.179	1.048400
11	220	9 10 34	219.156	14.681	1.166742
12	240	10 00 44	238.719	18.839	1.275052
13	260	10 50 56	258.118	23.705	1.374848
14	280	11 41 10	277.310	29.330	1.467311
15	300	12 31 26	296.249	35.759	1.553382
16	320	13 21 45	314.879	43.035	1.633817
17	340	14 12 06	333.138	51.196	1.709235
18	360	15 02 29	350.958	60.276	1.780142
19	380	15 52 55	368.264	70.301	1.846961
20	400	16 43 25	384.974	81.290	1.910043
		17 33 58			

c. CHORD-LENGTH = 21

n	nc	D_s	y	x	Log x
1	21	0° 47' 37"	21.000	0.0305	8.484915
2	42	1 35 14	42.000	.1527	9.183883
3	63	2 22 52	62.998	.4276	9.631035
4	84	3 10 30	83.992	.9162	9.962012
5	105	3 58 08	104.978	1.680	0.225221
6	126	4 45 47	125.949	2.779	0.443844
7	147	5 33 27	146.896	4.274	0.630841
8	168	6 21 08	167.805	6.226	0.794210
9	189	7 08 50	188.660	8.694	0.939235
10	210	7 56 33	209.438	11.738	1.069589
11	231	8 44 18	230.114	15.415	1.187931
12	252	9 32 03	250.655	19.781	1.296242
13	273	10 19 51	271.023	24.891	1.396037
14	294	11 07 40	291.176	30.796	1.488500
15	315	11 55 31	311.062	37.547	1.574571
16	336	12 43 24	330.623	45.186	1.655007
17	357	13 31 20	349.795	53.756	1.730424
18	378	14 19 17	368.506	63.289	1.801331
19	399	15 07 17	386.677	73.816	1.868150
20	420	15 55 19	404.222	85.356	1.931232
		16 43 26			

c. CHORD-LENGTH = 22

<i>n</i>	<i>nc</i>	<i>D_s</i>	<i>y</i>	<i>x</i>	Log <i>x</i>
1	22	45' 27"	22.000	0.0320	8.505119
2	44	1° 30' 53"	44.000	.1600	9.204087
3	66	2 16 22	65.998	.4480	9.651238
4	88	3 01 50	87.992	.9599	9.982215
5	110	3 47 18	109.977	1.760	0.245424
6	132	4 32 48	131.947	2.911	0.464047
7	154	5 18 18	153.891	4.478	0.651045
8	176	6 03 48	175.796	6.522	0.814414
9	198	6 49 19	197.643	9.108	0.959438
10	220	7 34 51	219.411	12.297	1.089793
11	242	8 20 25	241.071	16.149	1.208134
12	264	9 06 00	262.591	20.723	1.316445
13	286	9 51 36	283.929	26.076	1.416240
14	308	10 37 13	305.042	32.263	1.508704
15	330	11 22 53	325.874	39.335	1.594775
16	352	12 08 34	346.367	47.338	1.675210
17	374	12 54 16	366.451	56.315	1.750628
18	396	13 40 01	386.054	66.303	1.821535
19	418	14 25 49	405.090	77.331	1.888353
		15 11 40			

c. CHORD-LENGTH = 23

<i>n</i>	<i>nc</i>	<i>D_s</i>	<i>y</i>	<i>x</i>	Log <i>x</i>
1	23	0° 43' 29"	23.000	0.0335	8.524424
2	46	1 26 58	46.000	.1673	9.223392
3	69	2 10 26	68.998	.4683	9.670543
4	92	2 53 56	91.991	1.004	0.001520
5	115	3 37 26	114.976	1.840	0.264729
6	138	4 20 56	137.945	3.043	0.483352
7	161	5 04 26	160.886	4.681	0.670350
8	184	5 47 58	183.787	6.819	0.833719
9	207	6 31 30	206.627	9.522	0.978743
10	230	7 15 04	229.384	12.856	1.109098
11	253	7 58 38	252.029	16.883	1.227439
12	276	8 42 13	274.527	21.665	1.335750
13	299	9 25 49	296.835	27.261	1.435545
14	322	10 09 27	318.907	33.729	1.528009
15	345	10 53 06	340.686	41.123	1.614080
16	368	11 36 47	362.110	49.490	1.694515
17	391	12 20 29	383.108	58.875	1.769933
18	414	13 04 13	403.602	69.317	1.840840
		13 47 59			

c. CHORD-LENGTH = 24

<i>n</i>	<i>nc</i>	<i>D_s</i>	<i>y</i>	<i>x</i>	Log <i>x</i>
1	24	41' 40"	24.000	0.0349	8.542907
2	48	1° 23' 20"	48.000	.1745	9.241875
3	72	2 05 00	71.998	.4887	9.689027
4	96	2 46 41	95.991	1.047	0.020004
5	120	3 28 22	119.975	1.920	0.283213
6	144	4 10 03	143.942	3.176	0.501836
7	168	4 51 45	167.881	4.885	0.688833
8	192	5 33 28	191.777	7.115	0.852202
9	216	6 15 10	215.611	9.936	0.997226
10	240	6 56 54	239.358	13.415	1.127581
11	264	7 38 39	262.987	17.617	1.245923
12	288	8 20 25	286.463	22.607	1.354234
13	312	9 02 12	309.741	28.446	1.454029
14	336	9 44 00	332.773	35.196	1.546492
15	360	10 25 48	355.499	42.910	1.632563
16	384	11 07 39	377.854	51.641	1.712999
17	408	11 49 31	399.765	61.435	1.788416
		12 31 25			

c. CHORD-LENGTH = 25

n	nc	D_s	y	x	Log x
1	25	0° 40' 00''	25.000	0.0364	8.560636
2	50	1 20 00	50.000	.1818	9.259604
3	75	2 00 00	74.997	.5090	9.706755
4	100	2 40 01	99.991	1.091	0.037732
5	125	3 20 02	124.974	2.000	0.300942
6	150	4 00 03	149.940	3.308	0.519564
7	175	4 40 04	174.876	5.088	0.706562
8	200	5 20 06	199.768	7.412	0.869931
9	225	6 00 09	224.595	10.350	1.014955
10	250	6 40 13	249.331	13.974	1.145310
11	275	7 20 17	273.945	18.351	1.263652
12	300	8 00 22	298.398	23.548	1.371962
13	325	8 40 28	322.647	29.632	1.471758
14	350	9 20 35	346.638	36.662	1.564221
15	375	10 00 43	370.311	44.698	1.650292
16	400	10 40 52	393.598	53.793	1.730727
17	425	11 21 03	416.421	63.995	1.806145
		12 01 16			

c. CHORD-LENGTH = 26

n	nc	D_s	y	x	Log x
1	26	0° 38' 28''	26.000	0.0378	8.577669
2	52	1 16 56	52.000	.1891	9.276637
3	78	1 55 24	77.997	.5294	9.723789
4	104	2 33 52	103.990	1.134	0.054766
5	130	3 12 20	129.973	2.080	0.317975
6	156	3 50 48	155.937	3.440	0.536598
7	182	4 29 18	181.871	5.292	0.723595
8	208	5 07 48	207.759	7.708	0.886964
9	234	5 46 18	233.579	10.764	1.031989
10	260	6 24 48	259.304	14.533	1.162343
11	286	7 03 20	284.903	19.085	1.280685
12	312	7 41 52	310.334	24.490	1.388996
13	338	8 20 25	335.553	30.817	1.488791
14	364	8 58 59	360.504	38.129	1.581254
15	390	9 37 33	385.124	46.486	1.667325
16	416	10 16 09	409.341	55.945	1.747761
		10 54 47			

c. CHORD-LENGTH = 27

n	nc	D_s	y	x	Log x
1	27	0° 37' 02''	27.000	0.0393	8.594060
2	54	1 14 04	54.000	.1963	9.293028
3	81	1 51 07	80.997	.5498	9.740179
4	108	2 28 10	107.990	1.178	0.071156
5	135	3 05 12	134.972	2.160	0.334365
6	162	3 42 15	161.935	3.573	0.552988
7	189	4 19 19	188.866	5.495	0.739986
8	216	4 56 23	215.750	8.005	0.903355
9	243	5 33 28	242.562	11.178	1.048379
10	270	6 10 32	269.277	15.092	1.178734
11	297	6 47 38	295.860	19.819	1.297075
12	324	7 24 44	322.270	25.432	1.405386
13	351	8 01 51	348.459	32.002	1.505181
14	378	8 38 59	374.369	39.595	1.597645
15	405	9 16 07	399.936	48.274	1.683716
		9 53 16			

c. CHORD-LENGTH = 28

<i>n</i>	<i>nc</i>	<i>D_s</i>	<i>y</i>	<i>x</i>	Log <i>x</i>
1	28	0° 35' 42"	28.000	0.0407	8.609854
2	56	1 11 26	55.999	.2036	9.308822
3	84	1 47 08	83.997	.5701	9.755973
4	112	2 22 52	111.990	1.222	0.086950
5	140	2 58 36	139.971	2.240	0.350160
6	168	3 34 19	167.933	3.705	0.568782
7	196	4 10 03	195.862	5.699	0.755780
8	224	4 45 48	223.740	8.301	0.919149
9	252	5 21 32	251.546	11.592	1.064173
10	280	5 57 17	279.251	15.650	1.194528
11	308	6 33 03	306.818	20.553	1.312870
12	336	7 08 50	334.206	26.374	1.421180
13	364	7 44 36	361.365	33.188	1.520976
14	392	8 20 24	388.235	41.062	1.613439
15	410	8 56 13	414.748	50.062	1.699510
		9 32 04			

c. CHORD-LENGTH = 29

1	29	0° 34' 29"	29.000	0.0422	8.625094
2	58	1 08 58	57.999	.2109	9.324062
3	87	1 43 27	86.997	.5905	9.771213
4	116	2 17 56	115.989	1.265	0.102190
5	145	2 52 26	144.970	2.320	0.365400
6	174	3 26 55	173.930	3.837	0.584022
7	203	4 01 26	202.857	5.902	0.771020
8	232	4 35 56	231.731	8.598	0.934389
9	261	5 10 26	260.530	12.006	1.079413
10	290	5 44 57	289.224	16.209	1.209768
11	319	6 19 29	317.776	21.287	1.323110
12	348	6 54 01	346.142	27.316	1.436420
13	377	7 28 34	374.271	34.373	1.536216
14	406	8 03 07	402.100	42.528	1.628679
		8 37 40			

c. CHORD-LENGTH = 30

1	30	0° 33' 20"	30.000	0.0436	8.639817
2	60	1 06 40	59.999	.2182	9.338785
3	90	1 40 00	89.997	.6108	9.785937
4	120	2 13 20	119.989	1.309	0.116914
5	150	2 46 41	149.969	2.400	0.380123
6	180	3 20 02	179.928	3.970	0.598746
7	210	3 53 22	209.852	6.106	0.785743
8	240	4 26 44	239.722	8.894	0.949112
9	270	5 00 05	269.514	12.420	1.034137
10	300	5 33 27	299.197	16.768	1.224491
11	330	6 06 49	328.734	22.021	1.342833
12	360	6 40 12	358.078	28.258	1.451144
13	390	7 13 36	387.176	35.558	1.550939
14	420	7 47 00	415.965	43.995	1.643402
		8 20 25			

c. CHORD-LENGTH = 31

n	nc	D_s	y	x	Log x
1	31	0° 32' 15"	31.000	0.0451	8.654058
2	62	1 04 31	61.999	.2254	9.353026
3	93	1 36 47	92.997	.6312	9.800177
4	124	2 09 02	123.988	1.353	0.131154
5	155	2 41 18	154.968	2.479	0.394363
6	186	3 13 34	185.925	4.102	0.612986
7	217	3 45 50	216.847	6.309	0.799984
8	248	4 18 07	247.713	9.191	0.963353
9	279	4 50 24	278.498	12.834	1.108377
10	310	5 22 41	309.170	17.327	1.238732
11	341	5 54 59	339.692	22.755	1.357073
12	372	6 27 17	370.014	29.200	1.465384
13	403	6 59 35	400.082	36.743	1.565179
		7 31 53			

c. CHORD-LENGTH = 32

1	32	0° 31' 15"	32.000	0.0465	8.667846
2	64	1 02 30	63.999	.2327	9.366814
3	96	1 33 45	95.997	.6516	9.813965
4	128	2 05 00	127.988	1.396	0.144942
5	160	2 36 16	159.967	2.559	0.408152
6	192	3 07 31	191.923	4.234	0.626774
7	224	3 38 47	223.842	6.513	0.813772
8	256	4 10 03	255.703	9.487	0.977141
9	288	4 41 19	287.481	13.248	1.122165
10	320	5 12 36	319.144	17.886	1.252520
11	352	5 43 53	350.649	23.489	1.370862
12	384	6 15 10	381.950	30.142	1.479172
13	416	6 46 28	412.988	37.929	1.578968
		7 17 46			

c. CHORD-LENGTH = 33

1	33	0° 30' 19"	33.000	0.0480	8.681210
2	66	1 00 36	65.999	.2400	9.380178
3	99	1 30 55	98.997	.6719	9.827329
4	132	2 01 13	131.988	1.440	0.158306
5	165	2 31 32	164.966	2.639	0.421516
6	198	3 01 50	197.921	4.367	0.640138
7	231	3 32 09	230.837	6.716	0.827136
8	264	4 02 28	263.694	9.784	0.990505
9	297	4 32 48	296.465	13.662	1.135529
10	330	5 03 07	329.117	18.445	1.265884
11	363	5 33 27	361.607	24.223	1.384226
12	396	6 03 47	393.886	31.084	1.492536
13	429	6 34 07	425.872	39.114	1.592332
		7 04 29			

c. CHORD-LENGTH = 34

<i>n</i>	<i>nc</i>	<i>D_s</i>	<i>y</i>	<i>x</i>	Log <i>x</i>
1	34	0° 29' 25''	34.000	0.0495	8.694175
2	68	0 58 49	67.999	.2473	9.393143
3	102	1 28 14	101.996	.6923	9.840294
4	136	1 57 39	135.987	1.483	0.171271
5	170	2 27 04	169.965	2.719	0.434481
6	204	2 56 29	203.918	4.499	0.653103
7	238	3 25 55	237.832	6.920	0.840101
8	272	3 55 20	271.685	10.080	1.003470
9	306	4 24 46	305.449	14.076	1.148494
10	340	4 54 12	339.090	19.004	1.278849
11	374	5 23 38	372.565	24.957	1.397191
12	408	5 53 05	405.822	32.026	1.505501
		6 22 11			

c. CHORD-LENGTH = 35

1	35	0° 28' 34''	35.000	0.0509	8.706764
2	70	0 57 09	69.999	.2545	9.405732
3	105	1 25 43	104.996	.7127	9.852883
4	140	1 54 17	139.987	1.527	0.183860
5	175	2 22 52	174.964	2.799	0.447070
6	210	2 51 27	209.916	4.631	0.665692
7	245	3 20 01	244.827	7.123	0.852690
8	280	3 48 36	279.675	10.377	1.016059
9	315	4 17 12	314.433	14.490	1.161083
10	350	4 45 47	349.063	19.563	1.291438
11	385	5 14 23	383.523	25.691	1.409780
12	420	5 43 00	417.758	32.968	1.518090
		6 09 36			

c. CHORD-LENGTH = 36

1	36	0° 27' 47''	36.000	0.0524	8.718998
2	72	0 55 33	71.999	.2618	9.417967
3	108	1 23 20	107.996	.7330	9.865118
4	144	1 51 07	143.987	1.571	0.196095
5	180	2 18 54	179.963	2.879	0.459304
6	216	2 46 41	215.913	4.764	0.677927
7	252	3 14 28	251.822	7.327	0.864924
8	288	3 42 15	287.666	10.673	1.028293
9	324	4 10 03	323.417	14.905	1.173318
10	360	4 37 51	359.037	20.122	1.303673
11	396	5 05 39	394.480	26.425	1.422014
12	432	5 33 27	429.694	33.910	1.530325
		6 01 15			

c. CHORD-LENGTH = 37

n	nc	D_s	y	x	Log x
1	37	0° 27' 02''	37.000	0.0538	8.730898
2	74	0 54 03	73.999	.2691	9.429866
3	111	1 21 05	110.996	.7534	9.877017
4	148	1 48 07	147.986	1.614	0.207994
5	185	2 15 09	184.962	2.959	0.471203
6	222	2 42 11	221.911	4.896	0.689826
7	259	3 09 13	258.817	7.530	0.876824
8	296	3 36 15	295.657	10.970	1.040193
9	333	4 03 17	332.400	15.319	1.185217
10	370	4 30 20	369.010	20.681	1.315572
11	407	4 57 23	405.438	27.159	1.433913
		5 24 26			

c. CHORD-LENGTH = 38

1	38	0° 26' 19''	38.000	0.0553	8.742480
2	76	0 52 39	75.999	.2763	9.441448
3	114	1 18 57	113.996	.7737	9.888599
4	152	1 45 16	151.986	1.658	0.219576
5	190	2 11 35	189.961	3.039	0.482785
6	228	2 37 54	227.909	5.028	0.701408
7	266	3 04 14	265.812	7.734	0.888406
8	304	3 30 33	303.648	11.266	1.051774
9	342	3 56 53	341.384	15.733	1.196799
10	380	4 23 13	378.983	21.240	1.327154
11	418	4 49 33	416.396	27.893	1.445495
		5 15 53			

c. CHORD-LENGTH = 39

1	39	0° 25' 38''	39.000	0.0567	8.753761
2	78	0 51 17	77.999	.2836	9.452729
3	117	1 16 55	116.996	.7941	9.899880
4	156	1 42 34	155.985	1.702	0.220857
5	195	2 08 13	194.960	3.119	0.494066
6	234	2 33 51	233.906	5.160	0.712689
7	273	2 59 30	272.807	7.938	0.899687
8	312	3 25 09	311.638	11.563	1.063055
9	351	3 50 48	350.368	16.147	1.208080
10	390	4 16 28	388.956	21.799	1.338435
11	429	4 42 07	427.354	28.627	1.456776
		5 07 46			

c. CHORD-LENGTH = 40

<i>n</i>	<i>nc</i>	<i>D_s</i>	<i>y</i>	<i>x</i>	Log <i>x</i>
1	40	0° 25' 00''	40.000	0.0582	8.764756
2	80	0 50 00	79.999	.2909	9.463724
3	120	1 15 00	119.996	.8145	9.910875
4	160	1 40 00	159.985	1.745	0.241852
5	200	2 05 00	199.959	3.199	0.505062
6	240	2 30 01	239.904	5.293	0.723684
7	280	2 55 01	279.802	8.141	0.910682
8	320	3 20 01	319.629	11.859	1.074051
9	360	3 45 02	359.352	16.561	1.219075
10	400	4 10 03	398.929	22.358	1.349430
11	440	4 35 03	438.312	29.361	1.467772
		5 00 04			

c. CHORD-LENGTH = 41

1	41	0° 24' 24''	41.000	0.0596	8.775480
2	82	0 48 47	81.999	.2982	9.474448
3	123	1 13 10	122.996	.8348	9.921599
4	164	1 37 34	163.985	1.789	0.252576
5	205	2 01 57	204.958	3.279	0.515786
6	246	2 26 21	245.901	5.425	0.734408
7	287	2 50 45	286.797	8.345	0.921406
8	328	3 15 09	327.620	12.156	1.084775
9	369	3 39 33	368.336	16.975	1.229799
10	410	4 03 57	408.903	22.917	1.360154
		4 28 21			

c. CHORD-LENGTH = 42

1	42	0° 23' 49''	42.000	0.0611	8.785945
2	84	0 47 37	83.999	.3054	9.484913
3	126	1 11 26	125.996	.8552	9.932065
4	168	1 35 14	167.984	1.832	0.263042
5	210	1 59 02	209.957	3.359	0.526251
6	252	2 22 52	251.899	5.557	0.744874
7	294	2 46 41	293.792	8.548	0.931871
8	336	3 10 30	335.611	12.452	1.095240
9	378	3 34 19	377.319	17.389	1.240265
10	420	3 58 08	418.876	23.476	1.370619
		4 21 57			

c. CHORD-LENGTH = 43

n	nc	D_s	y	x	Log x
1	43	0° 23' 15''	43.000	0.0625	8.796164
2	86	0 46 31	85.999	.3127	9.495133
3	129	1 09 46	128.996	.8755	9.942284
4	172	1 33 02	171.984	1.876	0.273261
5	215	1 56 17	214.955	3.439	0.536470
6	258	2 19 33	257.897	5.690	0.755093
7	301	2 42 48	300.787	8.752	0.942090
8	344	3 06 04	343.601	12.749	1.105459
9	387	3 29 20	386.303	17.803	1.250484
10	430	3 52 35	428.849	24.035	1.380839
		4 15 50			

c. CHORD-LENGTH = 44

1	44	0° 22' 44''	44.000	0.0640	8.806149
2	88	0 45 27	87.999	.3200	9.505117
3	132	1 08 11	131.995	.8959	9.952268
4	176	1 30 55	175.984	1.920	0.283245
5	220	1 53 38	219.954	3.519	0.546454
6	264	2 16 22	263.894	5.822	0.765077
7	308	2 39 06	307.782	8.955	0.952075
8	352	3 01 50	351.592	13.045	1.115444
9	396	3 24 34	395.287	18.217	1.260468
10	440	3 47 18	438.822	24.594	1.390823
		4 10 02			

c. CHORD-LENGTH = 45

1	45	0° 22' 13''	45.000	0.0655	8.815908
2	90	0 44 27	89.999	.3272	9.514877
3	135	1 06 40	134.995	.9163	9.962028
4	180	1 28 53	179.983	1.963	0.293005
5	225	1 51 07	224.953	3.599	0.556214
6	270	2 13 20	269.892	5.954	0.774837
7	315	2 35 34	314.778	9.159	0.961834
8	360	2 57 48	359.583	13.341	1.125203
9	405	3 20 01	404.271	18.631	1.270228
10	450	3 42 15	448.796	25.153	1.400583
		4 04 28			

c. CHORD-LENGTH = 46

1	46	0° 21' 44''	46.000	0.0669	8.825454
2	92	0 43 29	91.999	.3345	9.524422
3	138	1 05 13	137.995	.9366	9.971573
4	184	1 26 58	183.983	2.007	0.302550
5	230	1 48 42	229.952	3.679	0.565759
6	276	2 10 26	275.889	6.087	0.784382
7	322	2 32 11	321.773	9.362	0.971380
8	368	2 53 56	367.573	13.638	1.134749
9	414	3 15 40	413.255	19.045	1.279773
10	460	3 37 24	458.769	25.712	1.410128
		3 59 08			

TABLE XXXVI.—DEGREES OF CURVES
AND COORDINATES x AND y

c. CHORD-LENGTH = 47

n	nc	D_s	y	x	$\text{Log } x$
1	47	0° 21' 16"	47.000	0.0684	8.834794
2	94	0 42 33	93.999	.3418	9.533762
3	141	1 03 50	140.995	.9570	9.980913
4	188	1 25 06	187.982	2.051	0.311890
5	235	1 46 23	234.951	3.759	0.575100
6	282	2 07 40	281.887	6.219	0.793722
7	329	2 28 57	328.763	9.566	0.980720
8	376	2 50 14	375.564	13.934	1.144089
9	423	3 11 31	422.238	19.459	1.289113
10	470	3 32 48	468.742	26.270	1.419468
		3 54 05			

c. CHORD-LENGTH = 48

1	48	0° 20' 50"	48.000	0.0698	8.843937
2	96	0 41 40	95.999	.3491	9.542905
3	144	1 02 30	143.995	.9774	9.990057
4	192	1 23 20	191.982	2.094	0.321034
5	240	1 44 10	239.950	3.839	0.584243
6	288	2 05 00	287.885	6.351	0.802866
7	336	2 25 51	335.763	9.769	0.989863
8	384	2 46 41	383.555	14.231	1.153232
9	432	3 07 31	431.222	19.873	1.298256
		3 28 21			

c. CHORD-LENGTH = 49

1	49	0° 20' 25"	49.000	0.0713	8.852892
2	98	0 40 49	97.999	.3563	9.551860
3	147	1 01 14	146.995	.9977	9.999011
4	196	1 21 38	195.982	2.138	0.329988
5	245	1 42 03	244.949	3.919	0.593198
6	294	2 02 27	293.882	6.484	0.811820
7	343	2 22 52	342.758	9.973	0.998818
8	392	2 43 17	391.546	14.527	1.162187
9	441	3 03 41	440.206	20.287	1.307211
		3 24 06			

c. CHORD-LENGTH = 50

1	50	0° 20' 00"	50.000	0.0727	8.861666
2	100	0 40 00	99.999	.3636	9.560634
3	150	1 00 00	149.995	1.018	0.007785
4	200	1 20 00	199.981	2.182	0.338762
5	250	1 40 00	249.948	3.999	0.601972
6	300	2 00 00	299.880	6.616	0.820594
7	350	2 20 00	349.753	10.176	1.007592
8	400	2 40 01	399.536	14.824	1.170961
9	450	3 00 01	449.190	20.701	1.315985
		3 20 02			

n	s	$\cos s$	$\log \text{vers } s$	$R 1^\circ \times$ $\text{vers } s$	$\sin s$	$\log \sin s$	s
1	0° 10'	.99999	4.626422	.024	.00291	7.463726	0° 10'
2	0 30	.99996	5.580662	.218	.00873	7.940842	0 30
3	1 00	.99985	6.182714	.873	.01745	8.241855	1 00
4	1 40	.99958	6.626392	2.424	.02908	8.463665	1 40
5	2 30	.99905	6.978536	5.453	.04362	8.639680	2 30
6	3 30	.99813	7.270726	10.687	.06105	8.785675	3 30
7	4 40	.99668	7.520498	18.994	.08136	8.910404	4 40
8	6 00	.99452	7.738630	31.388	.10453	9.019235	6 00
9	7 30	.99144	7.932227	49.018	.13053	9.115698	7 30
10	9 10	.98723	8.106221	73.173	.15931	9.202234	9 10
11	11 00	.98163	8.264176	105.270	.19081	9.280599	11 00
12	13 00	.97437	8.408748	146.857	.22495	9.352088	13 00
13	15 10	.96517	8.541968	199.570	.26163	9.417684	15 10
14	17 30	.95372	8.665422	265.186	.30071	9.478142	17 30
15	20 00	.93969	8.780370	345.540	.34202	9.534052	20 00
16	22 40	.92276	8.887829	442.543	.38537	9.585877	22 40
17	25 30	.90259	8.988625	558.153	.43051	9.633984	25 30
18	28 30	.87882	9.083441	694.335	.47716	9.678663	28 30
19	31 40	.85112	9.172846	853.050	.52498	9.720140	31 40
20	35 00	.81915	9.257314	1036.20	.57358	9.758591	35 00

NOTE.—These coordinates locate the point A' where the spiral arc $(n + 1)$ produced backward would meet a parallel tangent. They do not apply to the selected curve unless this has the same degree of curve as the spiral arc. (See Table XXXIX.)

CHORD, 10 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	18.334	11.667	30.000	.07	15.00
4	25.001	15.001	39.999	.15	20.00
5	31.670	18.337	49.996	.25	25.00
6	38.339	21.674	59.991	.41	29.99
7	45.017	25.016	69.980	.61	34.99
8	51.700	28.363	79.962	.87	39.98
9	58.390	31.719	89.933	1.20	44.96
10	65.094	35.086	99.889	1.60	49.94
11	71.816	38.469	109.824	2.08	54.91
12	78.560	41.873	119.731	2.64	59.87
13	85.333	45.304	129.602	3.30	64.81
14	92.144	48.768	139.429	4.06	69.73
15	99.001	52.276	149.200	4.92	74.63
16	105.916	55.835	158.903	5.90	79.50
17	112.902	59.459	168.524	6.99	84.34
18	119.972	63.161	178.048	8.21	89.13
19	127.144	66.956	187.457	9.56	93.88
20	134.439	70.863	196.731	11.04	98.58

CHORD, 11 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	20.17	12.83	33.00	.08	16.50
4	27.50	16.50	44.00	.16	22.00
5	34.84	20.17	55.00	.28	27.50
6	42.17	23.84	65.99	.45	32.99
7	49.52	27.52	76.98	.67	38.49
8	56.87	31.20	87.96	.96	43.98
9	64.23	34.89	98.93	1.32	49.46
10	71.60	38.59	109.88	1.76	54.94
11	79.00	42.32	120.81	2.28	60.40
12	86.42	46.06	131.70	2.91	65.86
13	93.87	49.83	142.56	3.63	71.29
14	101.36	53.65	153.37	4.46	76.71
15	108.90	57.50	164.12	5.41	82.09
16	116.51	61.42	174.79	6.49	87.45
17	124.19	65.41	185.38	7.69	92.77
18	131.97	69.48	195.85	9.03	98.05
19	139.86	73.65	206.20	10.51	103.27
20	147.88	77.95	216.40	12.14	108.43

CHORD, 12 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	22.00	14.00	36.00	.09	18.00
4	30.00	18.00	48.00	.17	24.00
5	38.00	22.00	60.00	.31	30.00
6	46.01	26.01	71.99	.49	35.99
7	54.02	30.02	83.98	.73	41.99
8	62.04	34.04	95.95	1.05	47.98
9	70.07	38.06	107.92	1.44	53.96
10	78.11	42.10	119.87	1.92	59.93
11	86.18	46.16	131.79	2.49	65.90
12	94.27	50.25	143.68	3.17	71.84
13	102.40	54.36	155.52	3.96	77.77
14	110.57	58.52	167.31	4.87	83.68
15	118.80	62.73	179.04	5.90	89.56
16	127.10	67.00	190.68	7.08	95.40
17	135.48	71.35	202.23	8.39	101.21
18	143.97	75.79	213.66	9.85	106.96
19	152.57	80.35	224.95	11.47	112.66
20	161.33	85.04	236.08	13.24	118.29

CHORD, 13 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	23.83	15.17	39.00	.09	19.50
4	32.50	19.50	52.00	.19	26.00
5	41.17	23.84	64.99	.33	32.50
6	49.84	28.18	77.99	.53	38.99
7	58.52	32.52	90.97	.79	45.49
8	67.21	36.87	103.95	1.13	51.97
9	75.91	41.23	116.91	1.56	58.45
10	84.62	45.61	129.86	2.08	64.93
11	93.36	50.01	142.77	2.70	71.39
12	102.13	54.43	155.65	3.43	77.83
13	110.93	58.89	168.48	4.29	84.25
14	119.79	63.40	181.26	5.27	90.65
15	128.70	67.96	193.96	6.40	97.02
16	137.69	72.59	206.57	7.67	103.35
17	146.77	77.30	219.08	9.09	109.64
18	155.96	82.11	231.46	10.67	115.87
19	165.29	87.04	243.69	12.42	122.05
20	174.77	92.12	255.75	14.35	128.15

CHORD, 14 FEET

<i>n</i>	Tangent SE.	Tangent LE.	L. Chord SL.	Offset <i>p</i> .	Dist. <i>q</i> .
3	25.67	16.33	42.00	.10	21.00
4	35.00	21.00	56.00	.20	28.00
5	44.34	25.67	69.99	.36	35.00
6	53.67	30.34	83.99	.57	41.99
7	63.02	35.02	97.97	.86	48.98
8	72.38	39.71	111.95	1.22	55.97
9	81.75	44.41	125.91	1.63	62.95
10	91.13	49.12	139.84	2.24	69.92
11	100.54	53.86	153.75	2.91	76.88
12	109.98	58.62	167.62	3.70	83.82
13	119.47	63.43	181.44	4.62	90.74
14	129.00	68.28	195.20	5.68	97.63
15	138.60	73.19	208.88	6.89	104.48
16	148.28	78.17	222.46	8.26	111.30
17	158.06	83.24	235.93	9.79	118.07
18	167.96	88.43	249.27	11.49	124.79
19	178.00	93.74	262.44	13.38	131.44
20	188.21	99.21	275.42	15.45	138.01

CHORD, 15 FEET

<i>n</i>	Tangent SE.	Tangent LE.	L. Chord SL.	Offset <i>p</i> .	Dist. <i>q</i> .
3	27.50	17.50	45.00	.11	22.50
4	37.50	22.50	60.00	.22	30.00
5	47.51	27.51	74.99	.38	37.50
6	57.51	32.51	89.99	.61	44.99
7	67.53	37.52	104.97	.92	52.48
8	77.55	42.54	119.94	1.31	59.97
9	87.59	47.58	134.90	1.80	67.45
10	97.64	52.63	149.83	2.40	74.91
11	107.72	57.70	164.74	3.11	82.37
12	117.84	62.81	179.60	3.96	89.80
13	128.00	67.96	194.40	4.95	97.22
14	138.22	73.15	209.14	6.09	104.60
15	148.50	78.41	223.80	7.38	111.95
16	158.87	83.75	238.35	8.85	119.25
17	169.35	89.19	252.79	10.49	126.51
18	179.96	94.74	267.07	12.31	133.70
19	190.72	100.43	281.19	14.33	140.82
20	201.66	106.29	295.10	16.55	147.86

CHORD, 16 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	29.33	18.67	48.00	.12	24.00
4	40.00	24.00	64.00	.23	32.00
5	50.67	29.34	79.99	.41	40.00
6	61.34	34.68	95.98	.65	47.99
7	72.03	40.03	111.97	.98	55.98
8	82.72	45.38	127.94	1.40	63.97
9	93.42	50.75	143.89	1.92	71.94
10	104.15	56.14	159.82	2.56	79.91
11	114.90	61.55	175.72	3.32	87.86
12	125.70	67.00	191.57	4.23	95.79
13	136.53	72.49	207.36	5.28	103.70
14	147.43	78.03	223.09	6.49	111.57
15	158.40	83.64	238.72	7.87	119.41
16	169.47	89.34	254.24	9.43	127.20
17	180.64	95.14	269.64	11.19	134.94
18	191.96	101.06	284.88	13.13	142.61
19	203.43	107.13	299.93	15.29	149.21
20	215.10	113.38	314.77	17.65	157.72

CHORD, 17 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	31.17	19.83	51.00	.12	25.50
4	42.50	25.50	68.00	.25	34.00
5	53.84	31.17	84.99	.43	42.50
6	65.18	36.85	101.98	.69	50.99
7	76.53	42.53	118.97	1.04	59.48
8	87.89	48.22	135.94	1.48	67.96
9	99.26	53.92	152.89	2.04	76.44
10	110.66	59.65	169.81	2.72	84.90
11	122.09	65.40	186.70	3.53	93.35
12	133.55	71.18	203.54	4.49	101.78
13	145.07	77.02	220.32	5.61	110.18
14	156.64	82.91	237.03	6.90	118.55
15	168.30	88.87	253.64	8.37	126.87
16	180.06	94.92	270.13	10.02	135.15
17	191.93	101.08	286.49	11.88	143.37
18	203.95	107.37	302.68	13.96	151.53
19	216.15	113.83	318.68	16.24	158.60
20	228.55	120.47	334.44	18.76	167.58

CHORD 18 FEET

<i>n</i>	Tangent SE.	Tangent LE.	L. Chord SL.	Offset <i>p</i> .	Dist. <i>q</i> .
3	33.00	21.00	54.00	.13	27.00
4	45.00	27.00	72.00	.26	36.00
5	57.01	33.01	89.99	.46	45.00
6	69.01	39.01	107.98	.73	53.99
7	81.03	45.03	125.96	1.10	62.98
8	93.06	51.05	143.93	1.57	71.96
9	105.10	57.09	161.88	2.16	80.94
10	117.17	63.16	179.80	2.88	89.90
11	129.27	69.24	197.68	3.74	98.84
12	141.41	75.37	215.51	4.75	107.76
13	153.60	81.55	233.28	5.94	116.66
14	165.86	87.78	250.97	7.30	125.52
15	178.20	94.10	268.56	8.86	134.34
16	190.65	100.50	286.03	10.61	143.10
17	203.22	107.03	303.34	12.58	151.81
18	215.95	113.69	320.49	14.78	160.44
19	228.86	120.52	337.42	17.20	167.99
20	241.99	127.55	354.12	19.86	177.44

CHORD, 19 FEET

<i>n</i>	Tangent SE.	Tangent LE.	L. Chord SL.	Offset <i>p</i> .	Dist. <i>q</i> .
3	34.83	22.17	57.00	.14	28.50
4	47.50	28.50	76.00	.28	38.00
5	60.17	34.84	94.99	.48	47.49
6	72.84	41.18	113.98	.77	56.99
7	85.53	47.53	132.96	1.16	66.48
8	98.23	53.89	151.93	1.66	75.96
9	110.94	60.27	170.87	2.28	85.43
10	123.68	66.66	189.79	3.04	94.89
11	136.45	73.09	208.66	3.95	104.33
12	149.26	79.56	227.49	5.02	113.75
13	162.13	86.08	246.24	6.27	123.14
14	175.07	92.66	264.91	7.71	132.49
15	188.10	99.32	283.48	9.35	141.80
16	201.24	106.09	301.92	11.20	151.05
17	214.51	112.97	320.20	13.28	160.24
18	227.95	120.01	338.29	15.60	169.35
19	241.57	127.22	356.17	18.16	177.38
20	255.43	134.64	373.79	20.97	187.30

CHORD, 20 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	36.67	23.33	60.00	.15	30.00
4	50.00	30.00	80.00	.29	40.00
5	63.34	36.67	99.99	.51	49.99
6	76.68	43.35	119.98	.81	59.99
7	90.04	50.03	139.96	1.22	69.98
8	103.40	56.73	159.92	1.74	79.96
9	116.78	63.44	179.87	2.40	89.93
10	130.19	70.17	199.78	3.20	99.89
11	143.63	76.94	219.65	4.15	109.83
12	157.12	83.75	239.46	5.28	119.74
13	170.67	90.61	259.20	6.60	129.62
14	184.29	97.54	278.86	8.11	139.47
15	198.00	104.55	298.40	9.84	149.26
16	211.83	111.67	317.81	11.79	159.00
17	225.80	118.92	337.04	13.98	168.68
18	239.94	126.32	356.10	16.42	178.27
19	254.29	133.91	374.91	19.11	186.76
20	268.88	141.73	393.46	22.07	197.15

CHORD, 21 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	38.50	24.50	63.00	.15	31.50
4	52.50	31.50	84.00	.31	42.00
5	66.51	38.51	104.99	.53	52.49
6	80.51	45.52	125.98	.86	62.99
7	94.54	52.53	146.96	1.28	73.48
8	108.57	59.56	167.92	1.83	83.96
9	122.62	66.61	188.86	2.52	94.43
10	136.70	73.68	209.77	3.36	104.88
11	150.81	80.79	230.63	4.36	115.32
12	164.98	87.93	251.43	5.55	125.73
13	179.20	95.14	272.16	6.93	136.10
14	193.50	102.41	292.80	8.52	146.44
15	207.90	109.78	313.32	10.33	156.73
16	222.42	117.25	333.70	12.38	166.95
17	237.09	124.86	353.90	14.68	177.11
18	251.94	132.64	373.90	17.24	187.18
19	267.00	140.61	393.66	20.07	196.15
20	282.32	148.81	413.13	23.18	207.01

CHORD, 22 FEET

<i>n</i>	Tangent SE.	Tangent LE.	L. Chord SL	Offset <i>p</i> .	Dist. <i>q</i> .
3	40.33	25.67	66.00	.16	33.00
4	55.00	33.00	88.00	.32	44.00
5	69.67	40.34	109.99	.56	54.99
6	84.35	47.68	131.98	.90	65.99
7	99.04	55.04	153.96	1.34	76.97
8	113.74	62.40	175.92	1.92	87.95
9	128.46	69.78	197.85	2.64	98.92
10	143.21	77.19	219.76	3.52	109.88
11	157.99	84.63	241.61	4.57	120.81
12	172.83	92.12	263.41	5.81	131.71
13	187.73	99.67	285.12	7.26	142.58
14	202.72	107.29	306.74	8.93	153.41
15	217.80	115.01	328.24	10.83	164.19
16	233.02	122.84	349.59	12.97	174.90
17	248.38	130.81	370.75	15.38	185.54
18	263.94	138.95	391.71	18.06	196.09
19	279.72	147.30	402.40	21.02	205.54

CHORD, 23 FEET

3	42.17	26.83	69.00	.17	34.50
4	57.50	34.50	92.00	.33	46.00
5	72.84	42.17	114.99	.59	57.49
6	88.18	49.85	137.98	.94	68.99
7	103.54	57.54	160.95	1.40	80.47
8	118.91	65.24	183.91	2.01	91.95
9	134.30	72.95	206.85	2.76	103.42
10	149.72	80.70	229.74	3.68	114.87
11	165.18	88.48	252.59	4.78	126.30
12	180.69	96.31	275.38	6.08	137.70
13	196.27	104.20	298.08	7.59	149.06
14	211.93	112.17	320.69	9.33	160.39
15	227.70	120.23	343.16	11.32	171.65
16	243.61	128.42	365.48	13.56	182.85
17	259.67	136.76	387.61	16.08	193.98
18	275.94	145.27	409.50	18.88	205.01

CHORD, 24 FEET

3	44.00	28.00	72.00	.17	36.00
4	60.00	36.00	96.00	.35	48.00
5	76.01	44.01	119.99	.61	59.99
6	92.01	52.02	143.98	.98	71.99
7	108.04	60.04	167.95	1.47	83.97
8	124.08	68.07	191.91	2.09	95.95
9	140.14	76.13	215.84	2.88	107.92
10	156.23	84.21	239.73	3.84	119.86
11	172.36	92.33	263.58	4.98	131.79
12	188.54	100.50	287.35	6.34	143.69
13	204.80	108.73	311.04	7.92	155.55
14	221.15	117.04	334.63	9.74	167.36
15	237.60	125.46	358.08	11.81	179.12
16	254.20	134.01	381.37	14.15	190.80
17	270.96	142.70	404.48	16.78	202.41

CHORD, 25 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	45.83	29.17	75.00	.18	37.50
4	62.50	37.50	100.00	.36	50.00
5	79.18	45.84	124.99	.64	62.49
6	95.85	54.19	149.98	1.02	74.99
7	112.54	62.54	174.95	1.53	87.47
8	129.25	70.91	199.91	2.18	99.95
9	145.98	79.30	224.83	3.00	112.41
10	162.74	87.72	249.72	4.00	124.86
11	179.54	96.17	274.56	5.19	137.28
12	196.40	104.68	299.33	6.60	149.67
13	213.33	113.26	324.00	8.25	162.03
14	230.36	121.92	348.57	10.14	174.33
15	247.50	130.69	373.00	12.30	186.58
16	264.79	139.59	397.26	14.74	198.75
17	282.25	148.65	421.31	17.48	210.85

CHORD, 26 FEET

3	47.67	30.33	78.00	.19	39.00
4	65.00	39.00	104.00	.38	52.00
5	82.34	47.68	129.99	.66	64.99
6	99.68	56.35	155.98	1.06	77.98
7	117.05	65.04	181.95	1.59	90.97
8	134.42	73.74	207.90	2.27	103.95
9	151.82	82.47	233.83	3.12	116.91
10	169.25	91.22	259.71	4.16	129.85
11	186.72	100.02	285.54	5.40	142.77
12	204.25	108.87	311.30	6.87	155.66
13	221.87	117.79	336.97	8.58	168.51
14	239.57	126.80	362.51	10.55	181.31
15	257.40	135.92	387.92	12.79	194.04
16	275.38	145.17	413.15	15.33	206.70

CHORD, 27 FEET

3	49.50	31.50	81.00	.20	40.50
4	67.50	40.50	108.00	.39	54.00
5	85.51	49.51	134.99	.69	67.49
6	103.52	58.52	161.97	1.10	80.98
7	121.55	67.54	188.95	1.65	94.47
8	139.59	76.58	215.90	2.36	107.94
9	157.65	85.64	242.82	3.24	121.40
10	175.75	94.73	269.70	4.31	134.85
11	193.90	103.87	296.52	5.61	148.26
12	212.11	113.06	323.27	7.13	161.65
13	230.40	122.32	349.93	8.91	174.99
14	248.79	131.67	376.46	10.95	188.28
15	267.30	141.14	402.84	13.29	201.51

CHORD, 28 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
3	51.33	32.67	84.00	.20	42.00
4	70.00	42.00	112.00	.41	56.00
5	88.68	51.34	139.99	.71	69.99
6	107.35	60.69	167.97	1.14	83.98
7	126.05	70.04	195.94	1.71	97.97
8	144.76	79.42	223.89	2.44	111.94
9	163.49	88.81	251.81	3.36	125.90
10	182.26	98.24	279.69	4.47	139.84
11	201.08	107.71	307.51	5.81	153.76
12	219.97	117.24	335.25	7.40	167.63
13	238.93	126.85	362.89	9.24	181.47
14	258.00	136.55	390.40	11.36	195.25
15	277.20	146.37	417.76	13.78	208.97

CHORD, 29 FEET

3	53.17	33.83	87.00	.21	43.50
4	72.50	43.50	116.00	.42	58.00
5	91.84	53.18	144.99	.74	72.49
6	111.18	62.86	173.97	1.18	86.98
7	130.55	72.55	202.94	1.77	101.47
8	149.93	82.25	231.89	2.53	115.94
9	169.33	91.98	260.81	3.48	130.40
10	188.77	101.75	289.68	4.63	144.84
11	208.26	111.56	318.49	6.02	159.25
12	227.82	121.43	347.22	7.66	173.62
13	247.47	131.38	375.85	9.57	187.95
14	267.22	141.43	404.34	11.77	202.23

CHORD, 30 FEET

3	55.00	35.00	90.00	.22	45.00
4	75.00	45.00	120.00	.44	60.00
5	95.01	55.01	149.99	.76	74.99
6	115.02	65.02	179.97	1.22	89.98
7	135.05	75.05	209.94	1.83	104.97
8	155.10	85.09	239.89	2.62	119.94
9	175.17	95.16	269.80	3.60	134.89
10	195.28	105.26	299.67	4.79	149.83
11	215.45	115.41	329.47	6.23	164.74
12	235.68	125.62	359.19	7.92	179.61
13	256.00	135.91	388.81	9.90	194.43
14	276.43	146.31	418.29	12.17	209.20

CHORD, 31 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	56.83	36.17	93.00	.23	46.50
4	77.50	46.50	124.06	.45	62.00
5	98.18	56.84	154.99	.79	77.49
6	118.85	67.19	185.97	1.26	92.98
7	139.55	77.55	216.94	1.89	108.46
8	160.27	87.93	247.88	2.70	123.94
9	181.01	98.33	278.79	3.72	139.39
10	201.79	108.77	309.66	4.95	154.82
11	222.63	119.25	340.45	6.44	170.23
12	243.53	129.81	371.16	8.19	185.60
13	264.53	140.44	401.77	10.23	200.91

CHORD, 32 FEET

3	58.67	37.33	96.00	.23	48.00
4	80.00	48.00	128.00	.47	64.00
5	101.35	58.68	159.99	.81	79.99
6	122.69	69.36	191.97	1.30	95.98
7	144.06	80.05	223.94	1.95	111.96
8	165.44	90.76	255.88	2.79	127.93
9	186.85	101.50	287.79	3.84	143.89
10	208.30	112.28	319.64	5.11	159.82
11	229.81	123.10	351.44	6.65	175.72
12	251.39	133.99	383.14	8.45	191.58
13	273.07	144.97	414.73	10.56	207.39

CHORD, 33 FEET

3	60.50	38.50	99.00	.24	49.50
4	82.50	49.50	132.00	.48	66.00
5	104.51	60.51	164.99	.84	82.49
6	126.52	71.53	197.97	1.34	98.98
7	148.56	82.55	230.93	2.02	115.46
8	170.61	93.60	263.88	2.88	131.93
9	192.69	104.67	296.78	3.96	148.38
10	214.81	115.78	329.63	5.27	164.81
11	236.99	126.95	362.42	6.85	181.21
12	259.25	138.18	395.11	8.72	197.57
13	281.58	149.50	427.69	10.89	213.87

CHORD, 34 FEET

<i>n</i>	Tangent SE.	Tangent LE.	L. Chord SL.	Offset <i>p</i> .	Dist. <i>q</i> .
3	62.33	39.67	102.00	.25	51.60
4	85.00	51.00	136.00	.49	68.00
5	107.68	62.34	169.99	.87	84.99
6	130.35	73.69	203.97	1.38	101.98
7	153.06	85.05	237.93	2.08	118.96
8	175.78	96.44	271.87	2.97	135.93
9	198.53	107.84	305.77	4.08	152.88
10	221.32	119.29	339.62	5.43	169.81
11	244.17	130.80	373.40	7.06	186.70
12	267.10	142.37	407.08	8.98	203.56

CHORD, 35 FEET

3	64.17	40.83	105.00	.25	52.50
4	87.50	52.50	140.00	.51	70.00
5	110.85	64.18	174.99	.89	87.49
6	134.19	75.86	209.97	1.43	104.98
7	157.56	87.56	244.93	2.14	122.46
8	180.95	99.27	279.87	3.05	139.93
9	204.37	111.02	314.77	4.20	157.38
10	227.83	122.80	349.61	5.59	174.80
11	251.35	134.64	384.38	7.27	192.19
12	274.96	146.56	419.06	9.24	209.54

CHORD, 36 FEET

3	66.00	42.00	108.00	.26	54.00
4	90.01	54.00	144.00	.52	72.00
5	114.01	66.01	179.99	.92	89.99
6	138.02	78.03	215.96	1.47	107.98
7	162.06	90.06	251.93	2.20	125.96
8	186.12	102.11	287.86	3.14	143.93
9	210.21	114.19	323.76	4.32	161.87
10	234.34	126.31	359.60	5.75	179.80
11	258.54	138.49	395.36	7.48	197.69
12	282.81	150.74	431.03	9.51	215.53

CHORD, 37 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	67.83	43.17	111.00	.27	55.50
4	92.51	55.50	148.00	.54	74.00
5	117.18	67.85	184.99	.94	92.49
6	141.86	80.20	221.97	1.51	110.98
7	166.56	92.56	258.93	2.26	129.46
8	191.29	104.94	295.86	3.23	147.92
9	216.04	117.36	332.75	4.44	166.37
10	240.85	129.82	369.59	5.91	184.79
11	265.72	142.34	406.35	7.68	203.18

CHORD, 38 FEET

3	69.67	44.33	114.00	.28	57.00
4	95.01	57.00	151.99	.55	76.00
5	120.35	69.68	189.98	.97	94.99
6	145.69	82.36	227.96	1.55	113.98
7	171.07	95.06	265.92	2.32	132.96
8	196.46	107.78	303.86	3.31	151.92
9	221.88	120.53	341.75	4.56	170.87
10	247.36	133.33	379.58	6.07	189.78
11	272.90	146.18	417.33	7.89	208.67

CHORD, 39 FEET

3	71.50	45.50	117.00	.28	58.50
4	97.51	58.50	155.99	.57	78.00
5	123.51	71.51	194.98	.99	97.49
6	149.52	84.53	233.96	1.59	116.98
7	175.57	97.56	272.92	2.38	136.46
8	201.63	110.62	311.85	3.40	155.92
9	227.72	123.70	350.74	4.68	175.36
10	253.87	136.84	389.57	6.23	194.78
11	280.08	150.03	428.31	8.09	214.16

CHORD, 40 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
3	73.33	46.67	120.00	.29	60.00
4	100.01	60.01	159.99	.58	80.00
5	126.68	73.35	199.98	1.02	99.99
6	153.36	86.70	239.96	1.63	119.98
7	180.07	100.06	279.92	2.44	139.95
8	206.80	113.45	319.85	3.49	159.92
9	233.56	126.88	359.73	4.80	179.86
10	260.38	140.34	399.56	6.39	199.77
					219.65

CHORD, 41 FEET

3	75.17	47.83	123.00	.30	61.50
4	102.51	61.51	163.99	.60	82.00
5	129.85	75.18	204.98	1.04	102.49
6	157.19	88.87	245.96	1.67	122.98
7	184.57	102.57	286.92	2.50	143.45
8	211.97	116.29	327.85	3.58	163.91
9	239.40	130.05	368.73	4.92	184.36
10	266.89	143.85	409.54	6.55	204.77

CHORD, 42 FEET

3	77.00	49.00	126.00	.31	63.00
4	105.01	63.01	167.99	.61	84.00
5	133.02	77.01	209.98	1.07	104.99
6	161.02	91.03	251.96	1.71	125.98
7	189.07	105.07	293.92	2.56	146.95
8	217.14	119.13	335.84	3.66	167.91
9	245.24	133.22	377.72	5.04	188.85
10	273.40	147.36	419.53	6.71	209.76

CHORD, 43 FEET

n	Tangent SE.	Tangent NE.	L. Chord SL.	Offset p .	Dist. q .
3	78.83	50.17	129.00	.31	64.50
4	107.51	64.51	171.99	.63	86.00
5	136.18	78.85	214.98	1.09	107.49
6	164.86	93.20	257.96	1.75	128.97
7	193.58	107.57	300.91	2.63	150.45
8	222.31	121.96	343.84	3.75	171.91
9	251.08	136.39	386.71	5.16	193.35
10	279.91	150.87	429.52	6.87	214.76

CHORD, 44 FEET

3	80.67	51.33	132.00	.32	66.00
4	110.01	66.01	175.99	.64	88.00
5	139.35	80.68	219.98	1.12	109.99
6	168.69	95.37	263.96	1.79	131.97
7	198.08	110.07	307.91	2.69	153.95
8	227.48	124.80	351.83	3.84	175.91
9	256.92	139.56	395.71	5.28	197.84
10	286.42	154.38	439.51	7.03	219.75

CHORD, 45 FEET

3	82.50	52.50	135.00	.33	67.50
4	112.51	67.51	179.99	.65	90.00
5	142.52	82.52	224.98	1.15	112.49
6	172.53	97.54	269.96	1.83	134.97
7	202.58	112.57	314.91	2.75	157.45
8	232.65	127.63	359.83	3.93	179.91
9	262.76	142.73	404.70	5.40	202.34
10	292.92	157.89	449.50	7.19	224.74

CHORD, 46 FEET

3	84.33	53.67	138.00	.33	69.00
4	115.01	69.01	183.99	.67	91.99
5	145.68	84.35	229.98	1.17	114.99
6	176.36	99.70	275.96	1.87	137.97
7	207.08	115.07	321.91	2.81	160.95
8	237.82	130.47	367.83	4.01	183.90
9	268.60	145.91	413.69	5.52	206.84
10	299.43	161.40	459.49	7.35	229.74

CHORD, 47 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p .	Dist. q .
3	86.17	54.84	141.00	.34	70.50
4	117.51	70.51	187.99	.68	93.99
5	148.85	86.18	234.98	1.20	117.49
6	180.19	101.87	281.96	1.91	140.97
7	211.58	117.58	328.91	2.87	164.45
8	242.99	133.31	375.82	4.10	187.90
9	274.43	149.08	422.69	5.64	211.33
10	305.93	164.90	469.48	7.51	233.73

CHORD, 48 FEET

3	88.00	56.00	144.00	.35	72.00
4	120.01	72.01	191.99	.70	95.99
5	152.02	88.02	239.98	1.22	119.99
6	184.03	104.04	287.95	1.95	143.97
7	216.08	120.08	335.90	2.93	167.94
8	248.16	136.14	383.82	4.19	191.90
9	280.27	152.25	431.68	5.76	215.83

CHORD, 49 FEET

3	89.83	57.17	147.00	.36	73.50
4	122.51	73.51	195.99	.71	97.99
5	155.18	89.85	244.98	1.25	122.49
6	187.86	106.20	293.95	2.00	146.97
7	220.58	122.58	342.90	2.99	171.44
8	253.33	138.98	391.82	4.27	195.90
9	286.11	155.42	440.68	5.88	220.33

CHORD, 50 FEET

3	91.67	58.34	150.00	.36	75.00
4	125.01	75.01	199.99	.73	99.99
5	158.35	91.68	249.98	1.27	124.99
6	191.70	108.37	299.95	2.04	149.97
7	225.09	125.08	349.90	3.05	174.94
8	258.50	141.82	399.81	4.36	199.90
9	291.95	158.59	449.67	6.00	224.82

TABLE XXXIX.—SELECTED CURVES WITH
PROPER SPIRALS

D'	$n \ c$	s	$R' \text{ vers } s$	$R' \sin s$	q	p
1° 40'	3 40	1° 00'	0.524	59.999	59.987	0.291
1 40	4 50	1 40	1.454	99.989	99.992	0.727
2	3 33	1 00	0.436	50.000	48.997	0.236
2	4 42	1 40	1.212	83.326	84.658	0.620
2	5 50	2 30	2.727	124.967	124.981	1.272
2 30	3 27	1 00	0.349	40.001	40.996	0.201
2 30	4 33	1 40	0.970	66.663	65.325	0.470
2 30	5 40	2 30	2.181	99.976	99.983	1.018
2 30	6 47	3 30	4.275	139.924	141.963	1.944
3	3 22	1 00	0.291	33.335	32.663	0.157
3	4 28	1 40	0.808	55.554	56.436	0.414
3	5 33	2 30	1.818	83.317	81.649	0.821
3	6 38	3 30	3.563	116.607	111.302	1.465
3	7 44	4 40	6.332	155.401	152.381	2.623
3	8 50	6 00	10.464	199.658	199.878	4.360
3 20	3 20	1 00	0.262	30.003	29.995	0.145
3 20	4 25	1 40	0.727	50.000	49.991	0.364
3 20	5 30	2 30	1.636	74.987	74.982	0.764
3 20	6 35	3 30	3.207	104.950	104.966	1.424
3 20	7 40	4 40	5.699	139.865	139.937	2.442
3 20	8 45	6 00	9.417	179.697	179.886	3.924
3 20	9 50	7 30	14.707	224.390	224.800	5.994
4	4 21	1 40	0.606	41.669	42.323	0.310
4	5 25	2 30	1.364	62.493	62.481	0.636
4	6 29	3 30	2.672	87.463	86.467	1.165
4	7 33	4 40	4.750	116.561	114.276	1.966
4	8 37	6 00	7.848	149.757	145.900	3.122
4	9 41	7 30	12.257	187.003	181.333	4.718
4	10 46	9 10	18.297	228.237	230.532	7.415
4 10	4 20	1 40	0.582	40.003	39.990	0.291
4 10	5 24	2 30	1.309	59.994	59.981	0.611
4 10	6 28	3 30	2.565	83.966	83.967	1.140
4 10	7 32	4 40	4.560	111.901	111.941	1.953
4 10	8 36	6 00	7.535	143.769	143.897	3.138
4 10	9 40	7 30	11.867	179.526	179.826	4.694
4 10	10 44	9 10	17.565	219.111	219.711	7.029
5	5 20	2 30	1.091	50.000	49.979	0.509
5	6 23	3 30	2.138	69.979	67.966	0.905
5	7 27	4 40	3.800	93.260	95.606	1.695
5	8 30	6 00	6.279	119.819	119.903	2.615
5	9 33	7 30	9.807	149.619	146.846	3.855
5	10 37	9 10	14.639	182.610	186.400	6.042
5	11 40	11 00	21.060	218.720	219.592	8.301
5 20	5 19	2 30	1.023	46.877	48.103	0.497
5 20	6 22	3 30	2.004	65.608	66.339	0.907
5 20	7 25	4 40	3.563	87.435	87.441	1.525
5 20	8 28	6 00	5.887	112.335	111.405	2.414
5 20	9 31	7 30	9.408	140.275	138.223	3.426
5 20	10 34	9 10	13.725	171.204	167.886	5.279
5 20	11 37	11 00	19.745	205.060	200.378	7.414
5 50	5 17	2 30	0.935	42.862	42.120	0.425
5 50	6 20	3 30	1.833	59.988	59.964	0.813
5 50	7 23	4 40	3.258	79.946	80.940	1.423

D'	n	c	s	R' vers s	R' sin s	q	p
5° 50'	8	26	6° 00'	5.383	102.714	105.045	2.325
5 50	9	29	7 30	8.407	128.260	132.270	3.599
5 50	10	31	9 10	12.549	156.541	152.629	4.778
5 50	11	34	11 00	18.054	187.496	185.069	6.903
6	5	17	2 30	0.909	41.673	43.309	0.451
6	6	19	3 30	1.782	58.324	55.630	0.732
6	7	22	4 40	3.167	77.727	76.164	1.311
6	8	25	6 00	5.234	99.863	99.905	2.178
6	9	28	7 30	8.173	124.700	126.846	3.419
6	10	31	9 10	12.201	152.196	156.974	5.126
6	11	33	11 00	17.553	182.293	179.314	6.670
6 40	6	18	3 30	1.604	52.497	55.460	0.778
6 40	7	20	4 40	2.851	69.962	69.939	1.220
6 40	8	23	6 00	4.711	89.886	93.901	2.108
6 40	9	25	7 30	7.357	112.242	112.353	2.993
6 40	10	28	9 10	10.982	136.991	142.260	4.668
6 40	11	30	11 00	15.799	164.081	164.653	6.222
6 40	12	33	13 00	22.040	193.440	200.446	9.044
7	6	17	3 30	1.528	50.000	51.959	0.721
7	7	19	4 40	2.715	66.634	66.272	1.152
7	8	21	6 00	4.487	85.611	82.194	1.739
7	9	24	7 30	7.007	106.904	108.707	2.929
7	10	26	9 10	10.460	130.476	128.828	4.073
7	11	29	11 00	15.048	156.278	161.498	6.239
7	12	31	13 00	21.480	184.240	185.774	7.720
7 30	7	18	4 40	2.534	62.198	63.713	1.129
7 30	8	20	6 00	4.188	79.911	79.904	1.742
7 30	9	22	7 30	6.540	99.786	97.857	2.568
7 30	10	24	9 10	9.763	121.788	117.570	3.652
7 30	11	27	11 00	14.046	145.871	149.989	5.773
7 30	12	29	13 00	19.594	171.976	174.166	7.722
7 30	13	31	15 10	26.628	200.011	200.071	10.115
8	7	17	4 40	2.376	58.316	60.600	1.084
8	8	19	6 00	3.927	74.924	76.900	1.706
8	9	21	7 30	6.132	93.558	95.102	2.562
8	10	23	9 10	9.154	114.188	115.196	3.702
8	11	25	11 00	13.169	136.768	137.177	5.182
8	12	27	13 00	18.371	161.240	161.030	7.061
8	13	29	15 10	24.966	187.529	186.742	9.407
8 20	7	16	4 40	2.281	55.988	55.933	0.975
8 20	8	18	6 00	3.770	71.932	71.901	1.567
8 20	9	20	7 30	5.887	89.822	89.854	2.393
8 20	10	22	9 10	8.788	109.628	109.783	3.509
8 20	11	24	11 00	12.643	131.306	131.681	4.974
8 20	12	26	13 00	17.637	154.801	155.533	6.853
8 20	13	28	15 10	23.969	180.041	181.324	9.219
9	7	15	4 40	2.113	51.848	53.078	0.940
9	8	17	6 00	3.491	66.613	69.229	1.549
9	9	19	7 30	5.452	83.181	87.511	2.414
9	10	20	9 10	8.139	101.523	97.942	3.040
9	11	22	11 00	11.709	121.598	119.473	4.440
9	12	24	13 00	16.333	143.356	143.107	6.274
9	13	26	15 10	22.197	166.729	168.824	8.620
9	14	28	17 30	29.495	191.632	196.603	11.567

D'	n	c	s	R' vers s	R' sin s	q	p
9° 20'	7	14	4° 40'	2.037	50.000	47.931	0.812
9 20	8	16	6 00	3.367	64.240	63.612	1.377
9 20	9	18	7 30	5.258	80.217	81.491	2.194
9 20	10	20	9 10	7.849	97.904	101.561	3.330
9 20	11	21	11 00	11.291	117.264	112.850	4.124
9 20	12	23	13 00	15.751	138.246	136.281	5.914
9 20	13	25	15 10	21.406	160.787	161.860	8.226
9 20	14	27	17 30	28.444	184.803	189.566	11.151
10	8	15	6 00	3.135	59.966	59.895	1.312
10	9	17	7 30	4.908	74.881	77.844	2.130
10	10	18	9 10	7.326	91.392	88.126	2.735
10	11	20	11 00	10.540	109.465	109.691	4.141
10	12	22	13 00	14.704	129.051	133.540	6.019
10	13	23	15 10	19.982	150.092	146.743	7.279
10	14	25	17 30	26.552	172.511	174.127	10.110
10	15	27	20 00	34.597	196.212	203.724	13.677
10 40	8	14	6 00	2.947	56.228	55.642	1.204
10 40	9	16	7 30	4.603	70.213	73.528	2.021
10 40	10	17	9 10	6.870	85.695	83.850	2.632
10 40	11	19	11 00	9.883	102.639	105.559	4.064
10 40	12	20	13 00	13.787	121.007	117.712	5.052
10 40	13	22	15 10	18.737	140.736	143.193	7.339
10 40	14	23	17 30	24.897	161.757	157.150	8.832
10 40	15	25	20 00	32.441	183.981	186.330	12.257
11 20	8	13	6 00	2.774	52.931	50.948	1.080
11 20	9	15	7 30	4.332	66.095	68.662	1.878
11 20	10	16	9 10	6.467	80.669	78.903	2.476
11 20	11	18	11 00	9.303	96.621	100.619	3.909
11 20	12	19	13 00	12.978	113.910	112.873	4.919
11 20	13	21	15 10	17.638	132.482	138.541	7.253
11 20	14	22	17 30	23.437	152.270	152.772	8.826
11 20	15	24	20 00	30.538	179.191	176.308	12.372
11 20	16	25	22 40	39.111	195.142	198.456	14.682
12	9	14	7 30	4.092	62.436	63.337	1.704
12	10	15	9 10	6.251	76.202	73.397	2.133
12	11	17	11 00	8.788	91.271	95.011	3.690
12	12	18	13 00	12.263	107.603	107.244	4.695
12	13	19	15 10	16.661	125.147	120.065	5.859
12	14	21	17 30	22.139	143.839	147.337	8.657
12	15	22	20 00	28.847	163.602	162.272	10.488
12	16	24	22 40	36.946	184.337	193.517	14.695
12 30	8	12	6 00	2.516	48.007	47.882	1.042
12 30	9	13	7 30	3.930	59.948	56.841	1.453
12 30	10	15	9 10	5.865	73.166	76.433	2.519
12 30	11	16	11 00	8.438	87.634	87.691	3.306
12 30	12	17	13 00	11.771	103.315	99.596	4.242
12 30	13	19	15 10	15.997	120.160	125.052	6.525
12 30	14	20	17 30	21.257	138.107	139.203	8.073
12 30	15	21	20 00	27.698	157.082	153.980	9.849
12 30	16	23	22 40	35.473	176.991	185.119	14.017
12 30	17	24	25 30	44.740	197.723	202.042	16.695
13 20	7	10	4 40	1.427	35.040	34.911	0.608
13 20	8	11	6 00	2.359	45.019	42.879	0.902
13 20	9	12	7 30	3.685	56.216	51.590	1.283
13 20	10	14	9 10	5.500	68.612	71.013	2.325
13 20	11	15	11 00	7.913	82.179	82.188	3.097

D'	$n \cdot c$	s	$R' \text{ vers } s$	$R' \sin s$	q	p
13° 20'	12 16	13° 00'	11.039	96.884	94.091	4.032
13 20	13 17	15 10	15.001	112.680	106.720	5.149
13 20	14 18	17 30	19.934	129.511	120.068	6.463
13 20	15 20	20 00	25.974	146.968	149.281	9.785
13 20	16 21	22 40	33.266	165.974	164.649	11.920
13 20	17 23	25 30	41.955	185.416	197.692	16.920
14 10	8 11	6 00	2.221	42.384	45.514	1.040
14 10	9 12	7 30	3.469	52.925	54.881	1.499
14 10	10 13	9 10	5.178	64.595	65.057	2.088
14 10	11 14	11 00	7.467	77.368	76.041	2.809
14 10	12 15	13 00	10.392	91.212	87.827	3.737
14 10	13 16	15 10	14.123	106.083	100.411	4.841
14 10	14 18	17 30	18.767	121.928	127.651	7.630
14 10	15 19	20 00	24.453	138.680	142.757	9.518
14 10	16 20	22 40	31.318	156.257	158.622	11.717
14 10	17 21	25 30	39.499	174.561	175.234	14.257
14 10	18 22	28 30	49.136	193.475	192.579	17.167
15	8 10	6 00	2.098	40.041	39.866	0.867
15	9 11	7 30	3.277	50.000	48.822	1.277
15	10 12	9 10	4.892	61.025	58.654	1.815
15	11 13	11 00	7.038	73.092	69.369	2.504
15	12 14	13 00	9.818	86.171	80.932	3.369
15	13 15	15 10	13.343	100.220	93.368	4.436
15	14 17	17 30	17.729	115.190	120.524	7.201
15	15 18	20 00	23.102	131.016	135.608	9.081
15	16 19	22 40	29.587	147.621	151.514	11.296
15	17 20	25 30	37.316	164.913	168.225	13.880
15	18 21	28 30	46.421	182.783	185.723	16.868
16 40	9 10	7 30	2.951	45.030	44.808	1.189
16 40	10 11	9 10	4.406	54.960	54.746	1.742
16 40	11 12	11 00	6.338	65.827	65.666	2.470
16 40	12 13	13 00	8.842	77.606	77.561	3.403
16 40	13 14	15 10	12.016	90.259	90.423	4.578
16 40	14 15	17 30	15.967	103.740	104.243	6.030
16 40	15 16	20 00	20.805	117.994	119.005	7.802
16 40	16 17	22 40	26.646	132.948	134.699	9.933
16 40	17 18	25 30	33.607	148.522	151.302	12.469
16 40	18 19	28 30	41.807	164.615	168.795	15.455
16 40	19 20	31 40	51.362	181.112	187.152	18.939
18 20	10 10	9 10	4.008	50.000	49.732	1.581
18 20	11 11	11 00	5.767	59.887	60.649	2.307
18 20	12 12	13 00	8.044	70.603	72.628	3.259
18 20	13 13	15 10	10.932	82.115	85.661	4.477
18 20	14 14	17 30	14.526	94.380	99.737	6.005
18 20	15 15	20 00	18.928	107.347	114.840	7.891
18 20	16 16	25 30	30.575	135.120	131.390	10.382
18 20	17 17	28 30	38.034	149.760	148.554	13.200
18 20	18 18	31 40	46.729	164.769	166.668	16.542
18 20	19 19	35 00	56.761	180.023	185.702	20.465
20	11 10	11 00	5.290	54.941	54.637	2.050
20	12 11	13 00	7.380	64.772	66.523	2.981
20	13 12	15 10	10.029	75.333	79.538	4.194
20	14 13	20 00	17.365	98.481	94.081	5.878
20	15 14	22 40	22.240	110.962	109.453	7.884
20	16 15	25 30	28.049	123.961	125.892	10.348
20	17 16	28 30	34.893	137.392	143.374	13.328
20	18 17	31 40	42.869	151.161	161.863	16.887
20	19 18	35 00	52.073	165.154	181.322	21.088

D'	n c	s	R' vers s	R' sin s	q	p
22° 30'	12 10	13° 00'	6.569	57.653	61.706	2.850
22 30	14 11	17 30	11.862	77.068	75.453	4.269
22 30	15 12	20 00	15.456	87.657	90.092	5.999
22 30	16 13	22 40	19.795	98.767	105.904	8.177
22 30	18 14	28 30	31.058	122.264	123.406	11.135
22 30	19 15	31 40	38.158	134.547	141.651	14.568
22 30	20 16	35 00	46.350	147.003	160.976	18.682
25	14 10	17 30	10.692	69.466	69.189	3.973
25	15 11	20 00	13.932	79.010	83.927	5.735
25	17 12	25 30	22.504	101.769	98.114	8.214
25	18 13	28 30	27.995	110.229	117.894	11.184
25	20 14	35 00	41.778	132.502	136.979	15.125
27 30	15 10	20 00	12.638	71.948	76.177	5.251
27 30	17 11	25 30	20.492	90.563	92.663	7.666
27 30	19 12	31 40	31.319	110.435	110.523	10.862
27 30	20 13	35 00	38.044	120.659	129.574	14.795
30	17 10	25 30	18.819	83.168	83.401	6.779
30	19 11	31 40	28.762	101.418	101.127	9.903
30	20 12	35 00	34.937	110.806	120.178	13.837
32 20	18 10	28 30	21.762	85.687	89.792	8.376
32 20	20 11	35 00	32.476	103.001	108.734	12.234
35	20 10	35 00	30.071	95.372	97.115	10.574

SELECTED SPIRALS FOR A 2° CURVE

Δ	s	$n \times c$	$D_{s(n+1)}$	D'	d	x	h
10°	1° 00'	3 × 32	2 05' 00"	2° 03'	41.12	.6516	.040
10	1 40	4 × 29	2 08 13	2 09	61.04	1.702	.187
10	2 30	5 × 43	2 19 33	2 18	73.69	3.439	.354
10	3 30	6 × 45	2 35 34	2 33	78.81	5.954	.590
10	4 40	7 × 44	3 01 50	2 40	70.47	8.955	.897
20°	1 00	3 × 33	2 01 13	2 01	45.28	.6719	.122
20	1 40	4 × 41	2 01 57	2 02	73.85	1.789	.118
20	2 30	5 × 48	2 05 00	2 05	99.99	3.839	.527
20	3 30	6 × 50	2 20 00	2 06	109.52	6.616	.554
30°	1 00	3 × 34	1 57 39	2 01	46.14	.6923	.566
30	1 40	4 × 41	2 01 57	2 01	75.16	1.789	.227
30	2 30	5 × 49	2 02 27	2 02	109.78	3.919	.377
30	3 30	6 × 50	2 20 00	2 02	115.63	6.616	.249
30	3 30	6 × 50	2 20 00	2 03	110.90	6.616	1.013
40°	1 00	3 × 35	1 54 17	2 01	46.90	.7127	1.222
40	1 40	4 × 42	1 59 02	2 01	76.96	1.832	.848
40	2 30	5 × 50	2 00 00	2 01	117.87	3.999	.141

SELECTED SPIRALS FOR A 4° CURVE

10°	1° 00'	3 × 16	4° 10' 03"	4° 07'	20.22	.3258	.045
10	1 40	4 × 19	4 23 13	4 16	29.12	.8290	.080
10	2 30	5 × 22	4 32 48	4 39	38.75	1.760	.177
10	3 30	6 × 23	5 04 26	5 17	41.37	3.043	.305
20°	1 40	4 × 20	4 10 03	4 04	34.92	.8726	.081
20	2 30	5 × 24	4 10 03	4 09	50.72	1.920	.184
20	3 30	6 × 27	4 19 19	4 17	63.69	3.573	.375
20	4 40	7 × 30	4 26 44	4 31	78.07	6.106	.598
20	6 00	8 × 31	4 50 24	4 46	81.88	9.191	.910
20	7 30	9 × 32	5 12 36	5 16	85.40	13.248	1.310
30°	1 40	4 × 20	4 10 03	4 02	35.57	.8726	.137
30	2 30	5 × 25	4 00 03	4 04	57.39	2.000	.147
30	3 30	6 × 28	4 10 03	4 07	72.37	3.705	.284
30	4 40	7 × 32	4 10 03	4 14	93.09	6.513	.687
30	6 00	8 × 35	4 17 12	4 23	110.31	10.377	1.091
30	7 30	9 × 37	4 30 20	4 34	122.20	15.319	1.526
30	9 10	10 × 38	4 49 33	4 47	126.86	21.240	2.126
40°	2 30	5 × 25	4 00 03	4 02	58.91	2.000	.109
40	3 30	6 × 28	4 10 03	4 04	73.75	3.705	.361
40	4 40	7 × 32	4 10 03	4 08	94.65	6.513	.977
40	6 00	8 × 36	4 10 03	4 12	121.38	10.673	.973
40	7 30	9 × 39	4 16 28	4 17	142.86	16.147	1.100
40	9 10	10 × 41	4 28 21	4 26	154.34	22.917	2.186
60°	2 30	5 × 25	4 00 03	4 01	59.68	2.000	.180
60	3 30	6 × 29	4 01 26	4 02	81.04	3.837	.461
60	4 40	7 × 32	4 10 03	4 03	99.59	6.513	.572
60	6 00	8 × 36	4 10 03	4 05	125.81	10.673	1.074
60	7 30	9 × 40	4 10 03	4 08	154.42	16.561	1.718
80°	2 30	5 × 25	4 00 03	4 01	58.29	2.000	.979
80	3 30	6 × 29	4 01 26	4 01	82.82	3.837	.295
80	4 40	7 × 33	4 02 28	4 02	106.99	6.716	1.000
80	6 00	8 × 37	4 03 17	4 03	135.61	10.970	1.199
80	7 30	9 × 41	4 03 57	4 05	164.79	16.975	2.440

SELECTED SPIRALS FOR AN 8° CURVE

Δ	s	$n \times c$	$D_s(n+1)$	D'	d	x	h
10°	2° 30'	5 × 11	9° 06' 01"	9° 06'	19.95	.8798	.051
20°	2 30	5 × 12	8 20 26	8 16	25.71	.9598	.051
20	3 30	6 × 14	8 20 26	8 34	34.86	1.852	.117
20	4 40	7 × 15	8 53 51	8 54	39.90	3.053	.185
20	6 00	8 × 16	9 23 07	9 24	45.52	4.744	.221
30°	2 30	5 × 12	8 20 26	8 07	26.50	.9598	.049
30	3 30	6 × 14	8 20 26	8 14	36.16	1.852	.142
30	4 40	7 × 16	8 20 26	8 26	47.01	3.256	.260
30	6 00	8 × 17	8 49 55	8 36	53.13	5.040	.325
30	7 30	9 × 18	9 16 08	8 46	60.05	7.452	.287
30	9 10	10 × 19	9 39 36	9 14	65.70	10.620	.590
40°	2 30	5 × 12	8 20 26	8 04	26.93	.9598	.079
40	3 30	6 × 14	8 20 26	8 08	36.85	1.852	.181
40	4 40	7 × 16	8 20 26	8 14	48.25	3.256	.293
40	6 00	8 × 18	8 20 26	8 22	61.35	5.337	.330
40	7 30	9 × 19	8 46 49	8 30	68.07	7.866	.472
40	9 10	10 × 20	9 10 34	8 40	75.01	11.179	.629
40	11 00	11 × 21	9 32 03	8 54	82.13	15.415	.840
40	13 00	12 × 22	9 51 36	9 14	89.81	20.723	1.024
60°	2 30	5 × 12	8 20 26	8 02	27.30	.9598	.136
60	3 30	6 × 14	8 20 26	8 03	38.22	1.852	.083
60	4 40	7 × 16	8 20 26	8 06	49.75	3.256	.317
60	6 00	8 × 18	8 20 26	8 10	62.87	5.337	.539
60	7 30	9 × 20	8 20 26	8 16	77.16	8.280	.863
60	9 10	10 × 22	8 20 25	8 24	93.05	12.297	1.139
60	11 00	11 × 23	8 42 13	8 31	101.08	16.883	1.523
60	13 00	12 × 25	8 40 28	8 48	118.19	23.548	2.160
60	15 10	13 × 26	8 58 59	9 02	127.21	30.817	2.613
60	17 30	14 × 27	9 16 07	9 22	136.45	39.595	3.157
80°	4 40	7 × 17	7 50 57	8 04	57.04	3.460	.366
80	6 00	8 × 19	7 54 03	8 06	71.78	5.633	.408
80	7 30	9 × 20	8 20 26	8 08½	79.18	8.280	.860
80	9 10	10 × 22	8 20 25	8 13	95.23	12.297	1.346
80	11 00	11 × 24	8 20 25	8 19	112.67	17.617	1.719
80	13 00	12 × 26	8 20 25	8 28	130.86	24.490	2.738
80	15 10	13 × 27	8 38 59	8 34	140.88	32.002	3.119
80	17 30	14 × 28	8 56 13	8 42	150.55	41.062	3.809

SELECTED SPIRALS FOR A 16° CURVE

Δ	s	$n \times c$	$D_s(n+1)$	D'	d	x	h
30°	4° 40'	7 × 10	13° 21' 48"	18° 00'	33.59	2.035	.388
40°	6 00	8 × 10	15 02 34	17 14	36.14	2.965	.430
60°	7 30	9 × 10	16 43 31	16 32	38.47	4.140	.436
60	9 10	10 × 11	16 43 31	16 48	46.40	6.148	.576
60	11 00	11 × 12	16 43 31	17 14	54.62	8.808	.860
60	13 00	12 × 12	18 07 48	17 22	54.14	11.303	1.093
60	15 10	13 × 13	18 01 18	18 10	62.88	15.409	1.516
60	17 30	14 × 13	19 19 14	18 12	62.85	19.064	1.552
60	20 00	15 × 14	19 06 05	20 00	72.14	25.031	2.182
80°	7 30	9 × 10	16 43 31	16 16	39.74	4.140	.328
80	9 10	10 × 11	16 43 31	16 26	47.49	6.148	.680
80	11 00	11 × 12	16 43 31	16 38	56.19	8.808	.943
80	13 00	12 × 13	16 43 30	16 56	65.24	12.245	1.384
80	15 10	13 × 14	16 43 29	17 22	74.72	16.594	1.973
80	17 30	14 × 14	17 55 44	17 24	75.02	20.531	1.939
80	20 00	15 × 15	17 50 54	18 06	85.15	26.819	2.657
80	22 40	16 × 15	18 58 25	18 08	85.18	32.276	2.677
80	28 30	18 × 16	19 53 20	19 42	95.84	48.221	3.748

The References are to Davies' Legendre, Revised Edition.

No.	REFERENCE.	HYPOTHESES.	CONSEQUENCES.
1	IV., XI.	If a triangle is right angled,	The square on the hypotenuse is equal to the sum of the squares on the other two sides.
2	I., XI., Cor. 1....	If a triangle is equilateral,	It is equiangular.
3	I., XI.	If a triangle is isosceles,	The angles at the base are equal.
4	I., XI., Cor. 2....	If a straight line from the vertex of an isosceles triangle bisects the base,	It bisects the vertical angle. And is perpendicular to the base.
5	I., XXV., Cor. 6..	If one side of a triangle is produced,	The exterior angle is equal to the sum of the two interior and opposite angles.
6	IV., XX.	If two triangles are mutually equiangular,	They are similar. And their corresponding sides are proportional.
7	I., XXVII.	If the sides of a polygon are produced in the same order,	The sum of the exterior angles equals four right angles.
8	I., XXVI., Cor. 1.	If a figure is a quadrilateral,	The sum of the interior angles equals four right angles.
9	I., XXVIII. I., XXXI.	If a figure is a parallelogram,	The opposite sides are equal. The opposite angles are equal. It is bisected by its diagonal. And its diagonals bisect each other.
10	III., VII.	If three points are not in the same straight line,	A circle may be passed through them.
11	III., XVII.	If two arcs are intercepted on the same circle,	They are proportional to the corresponding angles at the centre.
12	V., XIII., Cor. 2..	If two arcs are similar,	They are proportional to their radii.
13	V., XIII.	If two areas are circles,	They are proportional to the squares on their radii.
14	III., VI.	If a radius is perpendicular to a chord,	It bisects the chord. And it bisects the arc subtended by the chord.
15	III., IX.	If a straight line is tangent to a circle,	It meets it in only one point. And it is perpendicular to the radius drawn to that point.
16	III., XIV., Cor... I., XI	If from a point without a circle tangents are drawn to touch the circle,	There are but two. They are equal. And they make equal angles with the chord joining the tangent points.

The References are to Davies' Legendre, Revised Edition.

No.	REFERENCE.	HYPOTHESES.	CONSEQUENCES.
17	III., X.....	If two lines are parallel chords or a tangent and parallel chord,	They intercept equal arcs of a circle.
18	III., XVIII.....	If an angle at the circumference of a circle is subtended by the same arc as an angle at the centre,	The angle at the circumference is equal to half the angle at the centre.
19	III., XVIII., Cor. 2	If an angle is inscribed in a semi-circle,	It is a right angle.
20	III., XXI.....	If an angle is formed by a tangent and chord,	It is measured by one half of the intercepted arc.
21	IV., XXVIII., Cor.	If two chords intersect each other in a circle,	The rectangle of the segments of the one, equals the rectangle of the segments of the other.
22	IV., XXIII., Cor. 2	And if one chord is a diameter, and the other perpendicular to it,	The rectangle of the segments of the diameter is equal to the square on half the other chord. And the half chord is a mean proportional between the segments of the diameter.
23	IV., XXIX., Cor..	If two secants meet without the circle,	The rectangles of each secant and its external segment are equal.
24	IV., XXX.....	If a secant and tangent meet,	The rectangle of the secant and its external segment is equal to the square on the tangent. And the tangent is a mean proportional between the secant and its external segment.
25	IV., XIV.....	If a straight line from the vertex of a triangle bisects its base,	The sum of the squares on the two sides is equal to twice the square of half the base increased by twice the square of the bisecting line.
26	IV., XII.....	If a perpendicular be drawn from the vertex of a triangle to the base,	The square of a side opposite an acute angle is equal to the sum of the squares of the other side and the base, diminished by twice the rectangle of the base and the distance from the vertex of the acute angle to the foot of the perpendicular.

THE TRIGONOMETRIC FUNCTIONS

In the figure, the ratio $\frac{a}{c}$ is called the sine of A

$\frac{b}{c}$ is called the cosine of A

$\frac{a}{b}$ is called the tangent of A

$\frac{b}{a}$ is called the cotangent of A

$\frac{c}{b}$ is called the secant of A

$\frac{c}{a}$ is called the cosecant of A

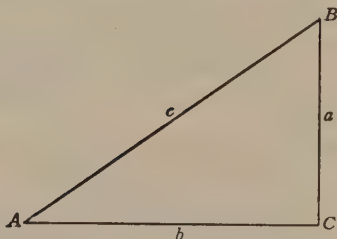
To these may be added, versine $A = 1 - \cosine A = \frac{c-b}{c}$

exsec $A = \sec A - 1 = \frac{c-b}{b}$

coversine $A = 1 - \sine A = \frac{c-a}{c}$

and

coexsec $A = \cscant - 1 = \frac{c-a}{a}$



The trigonometric functions are sometimes defined with reference to the sides of a right triangle, as follows, abbreviating $\sine A$ to $\sin A$, and so on:

$$\sin A = \frac{a}{c} = \frac{\text{opposite side}}{\text{hypotenuse}} = \cos B$$

$$\cos A = \frac{b}{c} = \frac{\text{adjacent side}}{\text{hypotenuse}} = \sin B$$

$$\tan A = \frac{a}{b} = \frac{\text{opposite side}}{\text{adjacent side}} = \cot B$$

$$\cot A = \frac{b}{a} = \frac{\text{adjacent side}}{\text{opposite side}} = \tan B$$

$$\sec A = \frac{c}{b} = \frac{\text{hypotenuse}}{\text{adjacent side}} = \csc B$$

$$\csc A = \frac{c}{a} = \frac{\text{hypotenuse}}{\text{opposite side}} = \sec B$$

The **complement** of an angle = 90° — the angle.

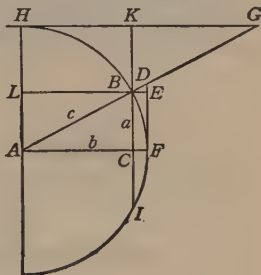
The **supplement** of an angle = 180° — the angle.

Again, the functions of an angle may be shown by use of a circle whose radius is unity or 1.

In the Figure, let A = angle BAC = arc BF , and let the radius AF = AB = AH = 1.

We then have,

$\sin A$	=	BC
$\cos A$	=	AC
$\tan A$	=	DF
$\cot A$	=	HG
$\sec A$	=	AD
$\operatorname{cosec} A$	=	AG
$\operatorname{versin} A$	=	$CF = BE$
$\operatorname{covers} A$	=	$BK = HL$
$\operatorname{exsec} A$	=	BD
$\operatorname{coexsec} A$	=	BG
$\operatorname{chord} A$	=	BF
$\operatorname{chord} 2A$	=	$BI = 2BC$



In the right-angled triangle ABC .

Let $AB = c$, $AC = b$, and $BC = a$.

We then have :

1. $\sin A = \frac{a}{c} = \cos B$
2. $\cos A = \frac{b}{c} = \sin B$
3. $\tan A = \frac{a}{b} = \cot B$
4. $\cot A = \frac{b}{a} = \tan B$
5. $\sec A = \frac{c}{b} = \operatorname{cosec} B$
6. $\operatorname{cosec} A = \frac{c}{a} = \sec B$
7. $\operatorname{vers} A = \frac{c-b}{c} = \operatorname{covers} B$
8. $\operatorname{exsec} A = \frac{c-b}{b} = \operatorname{coexsec} B$
9. $\operatorname{covers} A = \frac{c-a}{c} = \operatorname{versin} B$
10. $\operatorname{coexsec} A = \frac{c-a}{a} = \operatorname{exsec} B$

11. $a = c \sin A = b \tan A$
12. $b = c \cos A = a \cot A$
13. $c = \frac{a}{\sin A} = \frac{b}{\cos A}$
14. $a = c \cos B = b \cot B$
15. $b = c \sin B = a \tan B$
16. $c = \frac{a}{\cos B} = \frac{b}{\sin B}$
17. $a = \sqrt{(c+b)(c-b)}$
18. $b = \sqrt{(c+a)(c-a)}$
19. $c = \sqrt{a^2 + b^2}$
20. $C = 90^\circ = A + B$

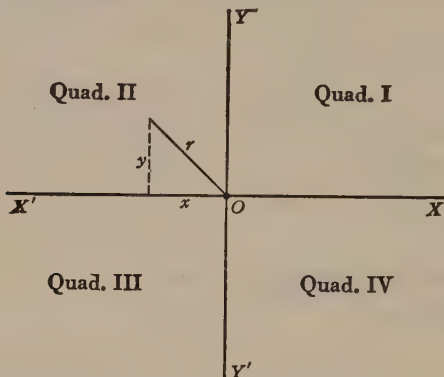
$$21. \text{area} = \frac{ab}{2}$$

SOLUTION OF RIGHT TRIANGLES

Equations 1 to 21, inclusive, will solve any right triangle.

The following *fundamental properties* of triangles will help in checking results:

1. *The sum of the interior angles of any triangle = 180° .*
2. *In any triangle the larger angle is opposite the larger side and conversely.*
3. *In any triangle the sum of two sides is larger than the third.*
4. *In a right triangle, the sum of the two acute angles = 90° , and either acute angle is the complement of the other.*
5. *In a right triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides.*



The figure shows the division of the circle into quadrants together with the customary designation I, II, III and IV, the first, second, third and fourth quadrants. The following will be of assistance in determining the signs of the functions in the different quadrants:

When x is measured in the direction OX it is positive (+), and when in the direction OX' it is negative (−); similarly, when y is measured in the direction OY it is positive (+), and when in the direction OY' it is negative (−).

For instance, consider the sin of an angle in the second quadrant (II).

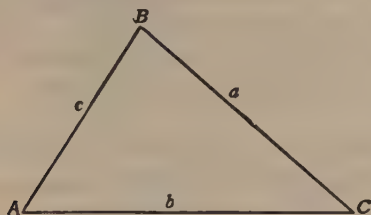
The general equation is $\sin A = \frac{y}{r}$. Here y is + and therefore $\sin A$ is +; $\cos A = \frac{x}{r}$. Here x is − and $\cos A$ is −. Similarly for the other functions in various quadrants.

From the above, the table given below has been compiled.

SIGNS OF THE FUNCTIONS IN THE FOUR QUADRANTS

Quadrant	sin	cos	tan	cot	sec	cosec
I = First	+	+	+	+	+	+
II = Second	+	−	−	−	−	+
III = Third	−	−	+	+	−	−
IV = Fourth	−	+	−	−	+	−

NOTE.—Oblique triangles may be solved by use of trigonometric formulas, or by resolving into right triangles.



SOLUTION OF OBLIQUE TRIANGLES BY USE OF FORMULAS

Let A , B and C be the angles of the triangle and a , b and c the sides opposite these angles.

	GIVEN	SOUGHT	FORMULAS
22	Case I A, B, a one side and any two angles	C, b, c , the re- maining parts	$C = 180^\circ - (A + B), \quad b = \frac{a}{\sin A} \cdot \sin B,$ $c = \frac{a}{\sin A} \sin (A + B) = \frac{a}{\sin A} \sin C$ Then, having found C and a, $\text{Area} = K = \frac{1}{2}ab \sin C = \frac{a^2 \sin B \sin C}{2 \sin A}$
23	Case II A, a, b , two sides and the angle opposite one of them	B, C, c ,	$\sin B = \frac{\sin A}{a} \cdot b, \quad C = 180^\circ - (A + B),$ $c = \frac{a}{\sin A} \cdot \sin C = \frac{b}{\sin B} \sin C$ REMARK. There may be two solutions. In order that there may be such, the given angle must be acute, and the side opposite it must be less than the side adjacent to it. $\text{Area} = K = \frac{1}{2}ab \sin C$
24	Case III C, a, b , two sides and the included angle	c , the other side; and B and A , the other angles	$c = \sqrt{a^2 + b^2 - 2ab \cos C}$ Then use the sine formula for the angles A and B $\sin A = \frac{a}{c} \sin C \text{ and } B = 180^\circ - (A + C) \text{ or solve}$ $\sin B = \frac{b}{c} \sin C \text{ and check } (A + B + C) = 180^\circ$
25			$\text{Again, } \cos B = \frac{a^2 + c^2 - b^2}{2ac}$
26			$\text{and } \cos A = \frac{b^2 + c^2 - a^2}{2bc}$

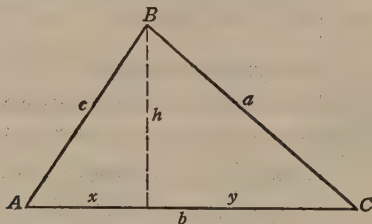
SOLUTION OF OBLIQUE TRIANGLE BY USE OF FORMULAS

	GIVEN	SOUGHT	FORMULAS
			Second Solution
		$\frac{1}{2}(A + B)$	$\frac{1}{2}(A + B) = 90^\circ - \frac{1}{2}C$
		$\frac{1}{2}(A - B)$	$\tan \frac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \frac{1}{2}(A + B)$
27	A, B		$A = \frac{1}{2}(A + B) + \frac{1}{2}(A - B),$ $B = \frac{1}{2}(A + B) - \frac{1}{2}(A - B)$
28	c		$c = (a + b) \frac{\cos \frac{1}{2}(A + B)}{\cos \frac{1}{2}(A - B)} = (a - b) \frac{\sin \frac{1}{2}(A + B)}{\sin \frac{1}{2}(A - B)}$
29	Area		$\text{Area} = K = \frac{1}{2}ab \sin C$

SOLUTION OF OBLIQUE TRIANGLES

30	Case IV $a, b, c,$ the three sides	$A,$ one angle, or, $A, B, C,$ all the angles	Let $s = \frac{1}{2}(a + b + c)$ Then $\sin \frac{1}{2}A = \sqrt{\frac{(s - b)(s - c)}{bc}}$ $\cos \frac{1}{2}A = \sqrt{\frac{s(s - a)}{bc}}$ $\tan \frac{1}{2}A = \sqrt{\frac{(s - b)(s - c)}{s(s - a)}}$ $\sin A = \frac{2\sqrt{s(s - a)(s - b)(s - c)}}{bc}$ $\text{vers } A = \frac{2(s - b)(s - c)}{bc}$
31			
32			B and C may then be found from the sin formula or, $\tan \frac{1}{2}B = \sqrt{\frac{(s - a)(s - c)}{s(s - b)}}$ and $\tan \frac{1}{2}C = \sqrt{\frac{(s - a)(s - b)}{s(s - c)}}$ Finally check by $(A + B + C) = 180^\circ$
33		area	$\text{Area} = K = \sqrt{s(s - a)(s - b)(s - c)}$

SOLUTION OF OBLIQUE TRIANGLES BY RE-SOLVING INTO RIGHT TRIANGLES



Let $A, B,$ and C denote the three angles and $a, b,$ and c the sides opposite these angles. Drop a perpendicular from B on the base AC . Denote this line by h and the parts of the base by x and y .

SOLUTION OF OBLIQUE TRIANGLES BY RE-SOLVING RIGHT TRIANGLES

GIVEN	SOUGHT	SOLUTION
Case I A, B, a , one side and <i>any</i> two angles	C, b, c	$C = 180^\circ - (A + B)$ Then use eq. (22) under Solution by Use of Formulas. In this case there is no advantage in a right triangle solution.
Case II A, a, b , two sides and the angle op- posite one of them	B, C, c	Here, also, use eq. (23) under Solution by Use of Formulas. When A, a , and c are given, the "right triangle" method may be used if preferred.
A, a, c	B, C, b	From the figure, $x = c \cos A$ $h = c \sin A$ $\sin C = \frac{h}{a}$ and $y = h \cot C$ Then $b = x + y$ Finally, $B = 180^\circ - (A + C)$ or <i>check on B</i> from the sin formula $\sin B = \frac{b}{a} \sin A$
Case III C, a, b , two sides and the included angle	c, A , and B , the remaining parts	From the figure, $y = a \cos C$; $h = a \sin C$ $x = b - a \cos C$ $\tan A = \frac{h}{x} = \frac{a \sin C}{b - a \cos C}$ Then $c = \frac{h}{\sin A} = \frac{x \tan A}{\sin A} = x \sec A = \frac{a \sin C}{\sin A}$ Finally, $B = 180^\circ - (A + C)$
Case IV a, b, c , the three sides	the three angles	$c^2 = x^2 + h^2$ $a^2 = y^2 + h^2$ Subtracting the second equation from the first, and $c^2 - a^2 = x^2 - y^2 = (x + y)(x - y)$ But $x + y = b$ and $y = b - x$ $\therefore c^2 - a^2 = b(x - y) = 2bx - b^2$ From which $x = \frac{b^2 + c^2 - a^2}{2b}$ From the figure $\cos A = \frac{x}{c} = \frac{b^2 + c^2 - a^2}{2bc}$ $\cos C = \frac{y}{a} = \frac{b - x}{a}$ Finally, $B = 180^\circ - (A + C)$

FUNCTIONS OF AN ANGLE IN TERMS OF OTHER FUNCTIONS OF SAME ANGLE

Function	$\sin A$	$\cos A$	$\tan A$	$\cot A$
$\sin A$	$\sin A$	$\sqrt{1 - \cos^2 A}$	$\frac{\pm \tan A}{\sqrt{1 + \tan^2 A}}$	$\frac{1}{\sqrt{1 + \cot^2 A}}$
$\cos A$	$\sqrt{1 - \sin^2 A}$	$\cos A$	$\frac{1}{\sqrt{1 + \tan^2 A}}$	$\frac{\cot A}{\sqrt{1 + \cot^2 A}}$
$\tan A$	$\frac{\sin A}{\sqrt{1 - \sin^2 A}}$	$\frac{\sqrt{1 - \cos^2 A}}{\cos A}$	$\tan A$	$\frac{1}{\cot A}$
$\cot A$	$\frac{\sqrt{1 - \sin^2 A}}{\sin A}$	$\frac{\cos A}{\sqrt{1 - \cos^2 A}}$	$\frac{1}{\tan A}$	$\cot A$
$\sec A$	$\frac{1}{\sqrt{1 - \sin^2 A}}$	$\frac{1}{\cos A}$	$\sqrt{1 + \tan^2 A}$	$\frac{\sqrt{1 + \cot^2 A}}{\cot A}$
$\operatorname{cosec} A$	$\frac{1}{\sin A}$	$\frac{1}{\sqrt{1 - \cos^2 A}}$	$\frac{\sqrt{1 + \tan^2 A}}{\tan A}$	$\sqrt{1 + \cot^2 A}$

Function	$\sec A$	$\operatorname{cosec} A$	$90^\circ - A$
$\sin A$	$\frac{\sqrt{\sec^2 A - 1}}{\sec A}$	$\frac{1}{\operatorname{cosec} A}$	$\cos (90^\circ - A)$
$\cos A$	$\frac{1}{\sec A}$	$\frac{\sqrt{\operatorname{cosec}^2 A - 1}}{\operatorname{cosec} A}$	$\sin (90^\circ - A)$
$\tan A$	$\sqrt{\sec^2 A - 1}$	$\frac{1}{\sqrt{\operatorname{cosec}^2 A - 1}}$	$\cot (90^\circ - A)$
$\cot A$	$\frac{1}{\sqrt{\sec^2 A - 1}}$	$\sqrt{\operatorname{cosec}^2 A - 1}$	$\tan (90^\circ - A)$
$\sec A$	$\sec A$	$\frac{\operatorname{cosec} A}{\sqrt{\operatorname{cosec}^2 A - 1}}$	$\operatorname{cosec} (90^\circ - A)$
$\operatorname{cosec} A$	$\frac{\sec A}{\sqrt{\sec^2 A - 1}}$	$\operatorname{cosec} A$	$\sec (90^\circ - A)$

FUNCTIONS OF ANGLES IN ANY QUADRANT IN TERMS OF ANGLES IN THE FIRST QUADRANT

	$90^\circ \pm A$	$180^\circ \pm A$	$270^\circ \pm A$	$360^\circ \pm A$
sin	$+\cos A$	$\mp \sin A$	$-\cos A$	$\pm \sin A$
cos	$\mp \sin A$	$-\cos A$	$\pm \sin A$	$+\cos A$
tan	$\mp \cot A$	$\pm \tan A$	$\mp \cot A$	$\pm \tan A$
cot	$\mp \tan A$	$\pm \cot A$	$\mp \tan A$	$\pm \cot A$
sec	$\mp \operatorname{cosec} A$	$-\sec A$	$\pm \operatorname{cosec} A$	$+\sec A$
cosec	$+\sec A$	$\mp \operatorname{cosec} A$	$-\sec A$	$\pm \operatorname{cosec} A$

NUMERICAL VALUES OF THE FUNCTIONS OF SOME ANGLES

Angle	0°	30°	45°	60°	90°	120°	135°	150°	180°	270°	360°
sine	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}\sqrt{3}$	1	$\frac{1}{2}\sqrt{3}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0	-1	0
cosine	1	$\frac{1}{2}\sqrt{3}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0	$-\frac{1}{2}$	$-\frac{1}{\sqrt{2}}$	$-\frac{\sqrt{3}}{2}$	-1	0	1
tangent	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	∞	$-\sqrt{3}$	-1	$-\frac{1}{\sqrt{3}}$	0	∞	0
cotangent	∞	$\sqrt{3}$	1	$\frac{1}{\sqrt{3}}$	0	$-\frac{1}{\sqrt{3}}$	-1	$-\sqrt{3}$	∞	0	∞
secant	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	∞	-2	$-\sqrt{2}$	$-\frac{2}{\sqrt{3}}$	-1	∞	1
cosecant	∞	2	$\sqrt{2}$	$\frac{2}{\sqrt{3}}$	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	∞	-1	∞

GENERAL FORMULAS

$$34 \quad \sin A = \frac{1}{\operatorname{cosec} A} = \sqrt{1 - \cos^2 A} = \tan A \cos A = \frac{\tan A}{\sqrt{1 + \tan^2 A}}$$

$$35 \quad \sin A = 2 \sin \frac{1}{2}A \cos \frac{1}{2}A = \operatorname{vers} A \cot \frac{1}{2}A$$

$$36 \quad \sin A = \sqrt{\frac{1}{2} \operatorname{vers} 2A} = \sqrt{\frac{1}{2} (1 - \cos 2A)}$$

$$37 \quad \cos A = \frac{1}{\sec A} = \sqrt{1 - \sin^2 A} = \cot A \sin A = \frac{1}{\sqrt{1 + \tan^2 A}}$$

$$38 \quad \cos A = 1 - \operatorname{vers} A = 2 \cos^2 \frac{1}{2}A - 1 = 1 - 2 \sin^2 \frac{1}{2}A$$

$$39 \quad \cos A = \cos^2 \frac{1}{2}A - \sin^2 \frac{1}{2}A = \sqrt{\frac{1}{2} + \frac{1}{2} \cos 2A}$$

$$40 \quad \tan A = \frac{1}{\cot A} = \frac{\sin A}{\cos A} = \sqrt{\sec^2 A - 1} = \frac{\sin A}{\sqrt{1 - \sin^2 A}}$$

$$41 \quad \tan A = \sqrt{\frac{1}{\cos^2 A} - 1} = \frac{\sqrt{1 - \cos^2 A}}{\cos A} = \frac{\sin 2A}{1 + \cos 2A}$$

$$42 \quad \tan A = \frac{1 - \cos 2A}{\sin 2A} = \frac{\operatorname{vers} 2A}{\sin 2A} = \operatorname{exsec} A \cot \frac{1}{2}A$$

$$43 \quad \cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A} = \sqrt{\operatorname{cosec}^2 A - 1} = \frac{\sqrt{1 - \sin^2 A}}{\sin A}$$

$$44 \quad \cot A = \frac{\sin 2A}{1 - \cos 2A} = \frac{\sin 2A}{\operatorname{vers} 2A} = \frac{1 + \cos 2A}{\sin 2A}$$

$$45 \quad \cot A = \frac{\tan \frac{1}{2}A}{\operatorname{exsec} A}$$

$$46 \quad \operatorname{vers} A = 1 - \cos A = \sin A \tan \frac{1}{2}A = 2 \sin^2 \frac{1}{2}A$$

$$47 \quad \operatorname{vers} A = \operatorname{exsec} A \cos A$$

$$48 \quad \operatorname{exsec} A = \sec A - 1 = \tan A \tan \frac{1}{2}A = \frac{\operatorname{vers} A}{\cos A}$$

FUNCTIONS OF HALF ANGLES

$$49 \quad \sin \frac{1}{2}A = \sqrt{\frac{1 - \cos A}{2}} = \sqrt{\frac{\operatorname{vers} A}{2}}$$

$$50 \quad \cos \frac{1}{2}A = \sqrt{\frac{1 + \cos A}{2}}$$

$$51 \quad \tan \frac{1}{2}A = \frac{\tan A}{1 + \sec A} = \operatorname{cosec} A - \cot A = \frac{1 - \cos A}{\sin A} = \sqrt{\frac{1 - \cos A}{1 + \cos A}}$$

$$52 \quad \cot \frac{1}{2}A = \frac{\sin A}{\operatorname{vers} A} = \frac{1 + \cos A}{\sin A} = \frac{1}{\operatorname{cosec} A - \cot A} = \sqrt{\frac{1 + \cos A}{1 - \cos A}}$$

GENERAL FORMULAS

FUNCTIONS OF HALF ANGLES

$$53 \quad \text{vers } \frac{1}{2} A = \frac{\frac{1}{2} \text{vers } A}{1 + \sqrt{1 - \frac{1}{2} \text{vers } A}} = \frac{1 - \cos A}{2 + \sqrt{2(1 + \cos A)}}$$

$$54 \quad \text{exsec } \frac{1}{2} A = \frac{1 - \cos A}{(1 + \cos A) + \sqrt{2(1 + \cos A)}}$$

FUNCTIONS OF DOUBLE ANGLES

$$55 \quad \sin 2 A = 2 \sin A \cos A$$

$$56 \quad \cos 2 A = 2 \cos^2 A - 1 = \cos^2 A - \sin^2 A = 1 - 2 \sin^2 A$$

$$57 \quad \tan 2 A = \frac{2 \tan A}{1 - \tan^2 A}$$

$$58 \quad \cot 2 A = \frac{\cot^2 A - 1}{2 \cot A}$$

$$59 \quad \text{vers } 2 A = 2 \sin^2 A = 2 \sin A \cos A \tan A$$

$$60 \quad \text{exsec } 2 A = \frac{2 \tan^2 A}{1 - \tan^2 A}$$

FUNCTIONS OF SUM OR DIFFERENCE OF TWO ANGLES

$$61 \quad \sin (A \pm B) = \sin A \cdot \cos B \pm \sin B \cdot \cos A$$

$$62 \quad \cos (A \pm B) = \cos A \cdot \cos B \mp \sin A \cdot \sin B$$

$$63 \quad \tan (A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$

SUMS AND DIFFERENCES OF TWO FUNCTIONS

$$64 \quad \sin A \pm \sin B = 2 \sin \frac{1}{2} (A \pm B) \cos \frac{1}{2} (A \mp B)$$

$$65 \quad \cos A + \cos B = 2 \cos \frac{1}{2} (A + B) \cos \frac{1}{2} (A - B)$$

$$66 \quad \cos B - \cos A = 2 \sin \frac{1}{2} (A + B) \sin \frac{1}{2} (A - B)$$

$$67 \quad \tan A \pm \tan B = \frac{\sin (A \pm B)}{\cos A \cdot \cos B}$$

$$68 \quad \sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A = \sin (A + B) \sin (A - B)$$

$$69 \quad \cos^2 A - \sin^2 B = \cos (A + B) \cos (A - B)$$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
SIMPLE CURVE FORMULAS			
1	1	D	$R = \frac{50}{\sin \frac{1}{2}D}$
2	2	R	$\sin \frac{1}{2}D = \frac{50}{R}$
3	3	Δ, D	$L = 100 \frac{\Delta}{D}$
4	4	D, L	$\Delta = \frac{DL}{100}$
5	5	Δ, L	$D = 100 \frac{\Delta}{L}$
6	6	R, Δ	$T = R \tan \frac{1}{2}\Delta$
7	7	"	$C = 2 R \sin \frac{1}{2}\Delta$
8	8	"	$M = R \text{ vers } \frac{1}{2}\Delta$
9	9	"	$E = R \text{ exsec } \frac{1}{2}\Delta$
10	10	T, Δ	$R = T \cot \frac{1}{2}\Delta$
11	11	"	$E = T \tan \frac{1}{4}\Delta$
12	....	"	$C = 2T \cos \frac{1}{2}\Delta$
13	....	"	$M = T \cot \frac{1}{2}\Delta \cdot \text{vers } \frac{1}{2}\Delta$
14	12	E, Δ	$R = \frac{E}{\text{exsec } \frac{1}{2}\Delta}$
15	13	"	$T = E \cot \frac{1}{4}\Delta$
16		R, d	$c = 2R \sin \frac{1}{2}d$
17	17	d, D	$c = 100 \frac{d}{D} \text{ (approx.)}$
18	22	R	$t = \frac{(100)^2}{2R}$
19	23	R, c	$t_1 = \frac{c^2}{2R}$
20	24	R, c	$t_1 = \frac{c^2 t}{(100)^2}$
21	40	Bp, Δ	$AA' = BB' = \frac{Bp}{\sin \Delta}$
22	42	R, Bp, Δ	$R' = R + \frac{Bp}{\text{vers } \Delta}$
23	44	BB', Δ	$R - R' = \frac{BB'}{\text{exsec } \Delta}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
SIMPLE CURVE FORMULAS			
24	45	R, R', Δ	$AA' = (R - R') \tan \Delta$
25	59	D, b, L	$D' = D \mp \frac{100}{L} \sin^{-1} \frac{2b}{L}$
26		E, Δ	$C = 2E \frac{\sin \frac{1}{2}\Delta}{\operatorname{exsec} \frac{1}{2}\Delta}$
27		"	$M = E \cos \frac{1}{2}\Delta$
28		C, Δ	$R = \frac{C}{2 \sin \frac{1}{2}\Delta}$
29		"	$M = \frac{1}{2}C \tan \frac{1}{4}\Delta$
30		"	$T = \frac{C}{2 \cos \frac{1}{2}\Delta}$
31		"	$E = \frac{1}{2}C \frac{\operatorname{exsec} \frac{1}{2}\Delta}{\sin \frac{1}{2}\Delta}$
32		M, Δ	$R = \frac{M}{\operatorname{vers} \frac{1}{2}\Delta}$
33		"	$C = 2M \cot \frac{1}{4}\Delta$
34		"	$T = M \frac{\tan \frac{1}{2}\Delta}{\operatorname{vers} \frac{1}{2}\Delta}$
35		"	$E = \frac{M}{\cos \frac{1}{2}\Delta}$
36		R, T	$\tan \frac{1}{2}\Delta = \frac{T}{R}$
37		"	$\sin \frac{1}{2}\Delta = \frac{T}{\sqrt{T^2 + R^2}}$
38		R, C	$\sin \frac{1}{2}\Delta = \frac{C}{2R}$
39		"	$\cos \frac{1}{2}\Delta = \frac{1}{R} \sqrt{\left(R + \frac{C}{2}\right) \left(R - \frac{C}{2}\right)}$
40		R, M	$\operatorname{vers} \frac{1}{2}\Delta = \frac{M}{R}$
41		"	$\cos \frac{1}{2}\Delta = \frac{R - M}{R}$
42		R, E	$\operatorname{exsec} \frac{1}{2}\Delta = \frac{E}{R}$
43		"	$\cos \frac{1}{2}\Delta = \frac{R}{R + E}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
SIMPLE CURVE FORMULAS			
44		T, C	$\cos \frac{1}{2}\Delta = \frac{C}{2T}$
45		"	$\tan \frac{1}{4}\Delta = \sqrt{\frac{2T-C}{2T+C}}$
46		T, E	$\tan \frac{1}{4}\Delta = \frac{E}{T}$
47		"	$\cos \frac{1}{2}\Delta = \frac{T^2 - E^2}{T^2 + E^2}$
48		C, M	$\tan \frac{1}{4}\Delta = \frac{2M}{C}$
49		"	$\cos \frac{1}{2}\Delta = \frac{C^2 - 4M^2}{C^2 + 4M^2}$
50		M, E	$\cos \frac{1}{2}\Delta = \frac{M}{E}$
51		"	$\tan \frac{1}{4}\Delta = \sqrt{\frac{E-M}{E+M}}$
52		R, T	$C = \frac{2TR}{\sqrt{T^2 + R^2}}$
53		"	$M = R - \frac{R^2}{\sqrt{T^2 + R^2}}$
54		"	$E = \sqrt{T^2 + R^2} - R$
55		R, C	$T = \frac{CR}{2\sqrt{\left(R + \frac{C}{2}\right)\left(R - \frac{C}{2}\right)}}$
56		"	$M = R - \sqrt{\left(R + \frac{1}{2}C\right)\left(R - \frac{1}{2}C\right)}$
57		"	$E = \frac{R^2}{\sqrt{\left(R + \frac{1}{2}C\right)\left(R - \frac{1}{2}C\right)}} - R$
58		R, M	$T = \frac{R\sqrt{M(2R-M)}}{R-M}$
59		"	$C = 2\sqrt{M(2R-M)}$
60		"	$E = \frac{RM}{R-M}$
61		R, E	$T = \sqrt{E(2R+E)}$
62		"	$C = \frac{2R\sqrt{E(2R+E)}}{R+E}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
SIMPLE CURVE FORMULAS			
63		R, E	$M = \frac{RE}{R + E}$
64		T, C	$R = \frac{CT}{\sqrt{(2T + C)(2T - C)}}$
65		"	$M = \frac{1}{2}C \sqrt{\frac{2T - C}{2T + C}}$
66		"	$E = T \sqrt{\frac{2T - C}{2T + C}}$
67		T, E	$R = \frac{(T + E)(T - E)}{2E}$
68		"	$C = \frac{2T(T^2 - E^2)}{T^2 + E^2}$
69		"	$M = \frac{E(T^2 - E^2)}{T^2 + E^2}$
70		C, M	$R = \frac{M^2 + (\frac{1}{2}C)^2}{2M}$
71		"	$T = \frac{C(C^2 + 4M^2)}{2(C^2 - 4M^2)}$
72		"	$E = M \frac{C^2 + 4M^2}{C^2 - 4M^2}$
73		M, E	$R = \frac{EM}{E - M}$
74		"	$T = E \sqrt{\frac{E + M}{E - M}}$
75		"	$C = 2M \sqrt{\frac{E + M}{E - M}}$
76		T, M	$R^3 - R^2 \frac{M^2 + T^2}{2M} + RT^2 - \frac{1}{2}MT^2 = 0$
77		"	$E^3 + E^2M - ET^2 + MT^2 = 0$
78		"	$C^3 + 2TC^2 + 4M^2C - 8M^2T = 0$
79		C, E	$R^3 + R^2 \frac{4E^2 - C^2}{8E} - R \frac{C^2}{4} - \frac{C^2E}{8} = 0$
80		"	$2T^3 - T^2C - 2TE^2 - CE^2 = 0$
81		"	$M^3 + M^2E + M \frac{C^2}{4} - \frac{C^2E}{4} = 0$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
COMPOUNDS AND REVERSED CURVES			
82	76	$\Delta, \Delta_2, R_1, R_2$	$T_1 \sin \Delta = R_1 \text{ vers } \Delta + (R_2 - R_1) \text{ vers } \Delta_2$
83	77	$\Delta, \Delta_1, R_1, R_2$	$T_2 \sin \Delta = R_2 \text{ vers } \Delta - (R_2 - R_1) \text{ vers } \Delta_1$
84	78	Δ, T_1, T_2, R_2	$\tan \frac{1}{2}\Delta_1 = \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{R_2 \sin \Delta - T_2 \cos \Delta - T_1}$
85	79	Δ, T_1, T_2, R_1	$\tan \frac{1}{2}\Delta_2 = \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{T_2 + T_1 \cos \Delta - R_1 \sin \Delta}$
86	76A	$\Delta, \Delta_2, R_1, R_2$	$T_1 = \frac{R_1 \text{ vers } \Delta + (R_2 - R_1) \text{ vers } \Delta_2}{\sin \Delta}$
87	76B	$\Delta, \Delta_2, R_1, R_2, T_1$	$R_2 = R_1 + \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{\text{vers } \Delta_2}$
88	76C	Δ, R_1, R_2, T_1	$\text{vers } \Delta_2 = \frac{T_1 \sin \Delta - R_1 \text{ vers } \Delta}{R_2 - R_1}$
89	77A	$\Delta, \Delta_2, R_1, R_2$	$T_2 = \frac{R_2 \text{ vers } \Delta - (R_2 - R_1) \text{ vers } \Delta_1}{\sin \Delta}$
90	77B	$\Delta, \Delta_1, R_2, T_2$	$R_1 = R_2 - \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{\text{vers } \Delta_1}$
91	77C	Δ, R_1, R_2, T_2	$\text{vers } \Delta_1 = \frac{R_2 \text{ vers } \Delta - T_2 \sin \Delta}{R_2 - R_1}$
92	144	p, r	$\text{vers } \Delta_r = \frac{\frac{1}{2}p}{r}$
93	145	p, Δ_r	$r = \frac{\frac{1}{2}p}{\text{vers } \Delta_r}$
94	146	p, Δ_r, r_1	$r_2 = \frac{p}{\text{vers } \Delta_r} - r_1$
95	147	p, r_1, r_2	$\text{vers } \Delta_r = \frac{p}{r_1 + r_2}$
96	152	l, Δ_1, Δ_2	$r = \frac{l}{\tan \frac{1}{2}\Delta_1 + \tan \frac{1}{2}\Delta_2}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
TURNOUTS			
97	158	F	$n = \frac{1}{2} \cot \frac{1}{2}F$
98	161	l, g, h, f, t, F, n	$L_a = l + [(g - h - f \sin F)]$ $\cot \frac{1}{2}(F + S) + f \cos F + nt$
99	162	g, h, f, F, S	$r + \frac{1}{2}g = \frac{g - h - f \sin F}{2 \sin \frac{1}{2}(F - S) \sin \frac{1}{2}(F + S)}$
100	169	h, r, g, S	$o = h - (r + \frac{1}{2}g) \text{ vers } S$
101	177	g, n	$L_s = 2gn$
102	178	g, n	$r = 2gn^2 = L_s n$
103	181	p, g, F	$d = \frac{p - g}{\sin F} - g \cot F$
104	183	g, k, F, r	$o_1 = g + k \sin F - (r + \frac{1}{2}g) \text{ vers } F$
105	.....	p, g, k, F	$r' - \frac{1}{2}g = \frac{p - g - k \sin F}{\text{vers } F}$
106	.....	g, r, F	$o = g - (r + \frac{1}{2}g) \text{ vers } F$

SPIRALS

107	222	x, x', y, y'	$\tan a = \frac{x - x'}{y - y'}$
108	223	a, s	$i = a - s$
109	224	x, y, i	$SL = \frac{y}{\cos i} = \frac{x}{\sin i}$
110	225	x, y, s	$LE = \frac{x}{\sin s}, SE = y - x \cot s$
111	228	x, R', s	$p = x - R' \text{ vers } s$
112	229	y, R', s	$q = y - R' \sin s$
113	230	y, x, Δ, R', s	$T_s = y + x \tan \frac{1}{2}\Delta + R' \frac{\sin (\frac{1}{2}\Delta - s)}{\cos \frac{1}{2}\Delta}$
114	232	R', n, c	$T_s = R' \tan \frac{1}{2}\Delta + \frac{1}{2}nc$ (approx.)
115	233	x, R', s, Δ	$E_s = \frac{x + R'(\cos s - \cos \frac{1}{2}\Delta)}{\cos \frac{1}{2}\Delta}$
116	237	R, R', x, s, Δ	$h \cos \frac{1}{2}\Delta = (R - R') \text{ vers } \frac{1}{2}\Delta - (x - R' \text{ vers } s)$
117	238	R, R', Δ, h	$p = (R - R') \text{ vers } \frac{1}{2}\Delta - h \cos \frac{1}{2}\Delta$
118	239	y, R, R', s, h, Δ	$d = y - R' \sin s - (R - R' + h) \sin \frac{1}{2}\Delta$ $- h = \frac{x - R \text{ vers } s}{\cos \frac{1}{2}\Delta} = \frac{p}{\cos \frac{1}{2}\Delta}$
119	244	x, R, s, Δ	
120	245	q, h, p, Δ	$d = q + h \sin \frac{1}{2}\Delta = q + p \tan \frac{1}{2}\Delta$
121	246	p, p', Δ	$AC = \frac{p'}{\sin \Delta} - \frac{p}{\tan \Delta} \quad BC' = \frac{p}{\sin \Delta} - \frac{p'}{\tan \Delta}$
122	247	q, q', AC, BC'	$d = q + AC \quad d' = q' + BC'$
123	253	p, Δ	$h = \frac{p}{\cos \frac{1}{2}\Delta}$
124	254	T, q, p, Δ	$T_s = T + q + p \tan \frac{1}{2}\Delta$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
THE TEN-CHORD SPIRAL			
125	255	R, L, l	$\frac{r}{R} = \frac{L}{l}$
126	256	D, L, l	$\frac{d}{D} = \frac{l}{L}$
127	257	L, D	$S = \frac{LD}{200}$
128	258	S, L, l	$\frac{s}{S} = \frac{l^2}{L^2}$
129	260A	D, L	$X = \frac{DL^2}{600}$
130		x, l	$i = \frac{x}{l} = \frac{Dl^2}{600L}$ (approx.)
131	261	s	$i = \frac{x}{3}$ (approx.)
132	262	l, i	$y = l \cos i$
133	264	x, y	$\tan I = \frac{X}{Y}$
134	267	S, I	$I' = S - I$
135	268	X, Y, R, s	$q = Y - R \sin s; p = X - R \text{ vers } s$
136	269	R, p, q, Δ	$T_s = (R + p) \tan \frac{1}{2}\Delta + q$
137	270	R, p, q, Δ	$E_s = (R + p) \text{ exsec } \frac{1}{2}\Delta + p$
EARTHWORK			
138	.....	b, s, d	$x = \frac{1}{2}b + sd$
139	.....	b, s, h, k	$\begin{cases} x = \frac{1}{2}b + sh \\ = \frac{1}{2}b + sk \end{cases}$
140	277	b, s, d	$A = bd + sd^2$
141	278	b, m, n, d	$A = \frac{1}{2}(b + m + n)d$
142	281	b, h, k, m, n	$A = \frac{1}{2}d(m + n) + \frac{1}{4}b(h + k)$
143	282	b, s, d, m, n	$A = \frac{1}{2} \left(d + \frac{b}{2s} \right) (m + n) - \frac{b^2}{4s}$
144	283	A, A', l	$S = \frac{l}{27} \frac{(A + A')}{2}$
145	284	A, A', M	$S = \frac{l}{6 \times 27} (A + 4M + A')$
146	285	SE, SP	$C = SE - SP$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
------------	----------	--------	-----------

EARTHWORK AND MISCELLANEOUS.

147	287	b, b', w, w'	$C = \frac{l}{12 \times 27} (w - w') (k - k')$
148	289	d, d', D, D'	$C = \frac{l}{12 \times 27} (d - d') (D - D')$
149	293	A, h	$S = \frac{A}{27} \left(\frac{h_1 + h_2 + h_3}{3} \right)$
150	294	A, h	$S = \frac{A}{27} \left(\frac{h_1 + h_2 + h_3 + h_4}{4} \right)$
151	295	A, s	$S = A \frac{s_1 + 2s_2 + 3s_3 + 4s_4}{4 \times 27}$
152	296	b, s, d	$S = \frac{100}{27} (bd + sd^2)$
153	298	b, a	$S = \frac{50}{54} ba$
154	299	$b, d, m,$ n, h, k	$SE = \frac{50}{54} d(m + n) + \frac{50}{54} \frac{1}{2} b(h + k)$
155	300	b, s, d, m, n	$SE = \frac{50}{54} \left(d + \frac{b}{2s} \right) (m + n) - \frac{50}{54} \frac{b^2}{2s}$
156	301	d, d', D, D'	$C = \frac{1}{3.24} (d - d') (D - D')$
157	306	l, A, A', S	$x = \frac{l^2(A - A')}{12 \times 27S}$
158	307	l, A, A'	$x = \frac{l}{6} \cdot \frac{A - A'}{A + A'}$
159	308	C, Δ	$M = \frac{1}{2} C \cdot \tan \frac{1}{4} \Delta$
160	309	D	$m = \frac{1}{2} 100 \tan \frac{1}{4} D$
161	310	R, c	$M = R - \sqrt{R^2 - \left(\frac{c}{2} \right)^2}$
162	313	R, c	$m_1 = \frac{c^2}{8R}$ (approx.)
163	315	n	$D = \frac{240}{n^2}$ (approx.)
164	316	n	$D = \frac{198}{n^2}$ (approx.)
165	.....	g, g', a	$n = \frac{g - g'}{2a}$
166	.....	g, g', n	$a = \frac{g - g'}{2n}$
167	324A	g, V, R	$e = .000686 V^2 D$ (in inches)

Title.	Symbol.	Number.	Loga- rithm.
Ratio of circumference to diameter	π	3.1415927	0.4971499
Reciprocal of same	$\frac{1}{\pi}$	0.3183099	9.5028501
Degrees in arc of length equal to radius.	$\frac{180^\circ}{\pi}$	57.295780	1.7581226
Minutes " " " " " .	$\frac{10800'}{\pi}$	3437.7468	3.5362739
Seconds " " " " " .	$\frac{648000''}{\pi}$	206264.81	5.3144251
Length of 1° arc, radius unity	$\frac{\pi}{180^\circ}$	.01745329	8.2418774
Length of $1'$ arc, " " 	$\frac{\pi}{10800}$	.00029089	6.4637261
Length of $1''$ arc, " " 	$\frac{\pi}{648000}$	.000004848	4.6855749
Radius by which 1 foot of arc = 1 degree.		57.295780	1.7581226
Radius " " $\frac{1}{10}$ " " = 1 minute.		343.77468	2.5362739
Radius " " $\frac{1}{100}$ " " = 10 seconds		206.26481	2.3144251
Factors for dividing a line into extreme { and mean ratio }		0.6180340 0.3819660	9.7910124 9.5820248
Base of hyperbolic logarithms	e	2.7182818	0.4342945
Modulus of common system of logs = $\log e$	M	0.4342945	9.6377843
Reciprocal of same = hyp. log. 10	$\frac{1}{M}$	2.3025851	0.3622157
Length of seconds pendulum at New York in inches (at 125 feet above sea level)		39.10299	1.5922100
Length of seconds pendulum at New York in feet		3.25858	0.5130244
Acceleration due to gravity at New York	g	32.1609	1.5073282
Square root of same	$\sqrt{g}$	5.67106	0.7536642
Yards in 1 meter		1.093611	0.0388629
Feet in 1 " 		3.280833	0.5159843
Inches in 1 " 		39.37	1.5951654
Meters in 1 foot		0.304801	9.4840235
Meters in 1 yard		0.914418	9.9611448
Meters in 1 mile		1609.344	3.2066489

Title.	Symbol.	Number.	Loga- rithm.
Cubic inches in 1 U. S. gallon		231.	2.3636120
“ “ “ 1 Imperial gallon.....		277.274	2.4429092
“ “ “ 1 U. S. bushel.....		2150.42	3.3325233
Cubic feet in 1 U. S. gallon.....		0.133681	9.1260683
“ “ “ 1 Imperial gallon.....		0.160459	9.2053655
“ “ “ 1 U. S. bushel.....		1.244456	0.0949796
Weight of 1 cub. foot of water, barom. 30 in. ther. 39°.83 Fah.; pounds..		62.379	1.7950384
“ 62° “ “ ..		62.321	1.7946349
Weight in grains, 1 cubic inch, at 62° Fah..		252.458	2.4021892
No. of grains in 1 pound avoird.....		7000.	3.8450980
“ “ “ 1 ounce “		437.5	2.6409781

r = radius of circular arc;
 l = length of arc;
 a° = degrees in same arc.

$$\left\{ \begin{aligned} a^\circ &= \frac{l}{r} \cdot \frac{180^\circ}{\pi} \\ r &= \frac{l}{a^\circ} \cdot \frac{180^\circ}{\pi} \\ l &= a^\circ r \cdot \frac{\pi}{180^\circ} \end{aligned} \right.$$

Radius by which the length of chord c in feet = $\frac{a'}{10}$ in minutes;

$$r = \frac{\frac{1}{2}a'}{10 \sin \frac{1}{2}a'}$$

Hyp. log x = com. log $x \times \frac{1}{M}$, or

$$\text{com. log (hyp. log } x) = \text{com. log (com. log } x) + 0.3622157$$

Com. log $x = M \times \text{hyp. log } x$; or

$$\text{com. log (com. log } x) = 9.6377843 + \text{com. log (hyp. log } x)$$

Circumference of circle (radius = r).....	$2\pi r$
Area of circle	πr^2
Area of sector (length of arc = l).....	$\frac{1}{2}lr$
Area of sector (angle of arc = a°).....	$\frac{a}{360} \pi r^2$
Approximate area of segment (chord = c , mid. ord. = m)	$\frac{2}{3}cm$

360 TABLE XLV.—DEFLECTIONS FOR TEN-CHORD
SPIRAL. TRANSIT AT *S*

<i>S</i>	1	2	3	4	5	6	7	8	9	10
0.0°	0° 00.00'	0° 00.0'	0° 00.0'	0° 00.0'	0° 00.0'	0° 00.0'	0° 00.0'	0° 00.0'	0° 00.0'	0° 00.0'
.1	00.02	00.1	00.2	00.3	00.5	00.7	01.0	01.3	01.6	02.0
.2	00.04	00.2	00.4	00.6	01.0	01.4	02.0	02.6	03.2	04.0
.3	00.06	00.2	00.5	01.0	01.5	02.2	02.9	03.8	04.9	06.0
.4	00.08	00.3	00.7	01.3	02.0	02.9	03.9	05.1	06.5	08.0
.5	00.10	00.4	00.9	01.6	02.5	03.6	04.9	06.4	08.1	10.0
.6	00.12	00.5	01.1	01.9	03.0	04.3	05.9	07.7	09.7	12.0
.7	00.14	00.6	01.3	02.2	03.5	05.0	06.9	09.0	11.3	14.0
.8	00.16	00.6	01.4	02.6	04.0	05.8	07.8	10.2	13.0	16.0
.9	00.18	00.7	01.6	02.9	04.5	06.5	08.8	11.5	14.6	18.0
1.0	00.20	0 00.8	0 01.8	0 03.2	0 05.0	0 07.2	0 09.8	0 12.8	0 16.2	0 20.0
.1	00.22	00.9	02.0	03.5	05.5	07.9	10.8	14.1	17.8	22.0
.2	00.24	01.0	02.2	03.8	06.0	08.6	11.8	15.4	19.4	24.0
.3	00.26	01.0	02.3	04.2	06.5	09.4	12.7	16.6	21.1	26.0
.4	00.28	01.1	02.5	04.5	07.0	10.1	13.7	17.9	22.7	28.0
.5	00.30	01.2	02.7	04.8	07.5	10.8	14.7	19.2	24.3	30.0
.6	00.32	01.3	02.9	05.1	08.0	11.5	15.7	20.5	25.9	32.0
.7	00.34	01.4	03.1	05.4	08.5	12.2	16.7	21.8	27.5	34.0
.8	00.36	01.4	03.2	05.8	09.0	13.0	17.6	23.0	29.2	36.0
.9	00.38	01.5	03.4	06.1	09.5	13.7	18.6	24.3	30.8	38.0
2.0	0 00.40	0 01.6	0 03.6	0 06.4	0 10.0	0 14.4	0 19.6	0 25.6	0 32.4	0 40.0
.1	00.42	01.7	03.8	06.7	10.5	15.1	20.6	26.9	34.0	42.0
.2	00.44	01.8	04.0	07.0	11.0	15.8	21.6	28.2	35.6	44.0
.3	00.46	01.8	04.1	07.4	11.5	16.6	22.5	29.4	37.3	46.0
.4	00.48	01.9	04.3	07.7	12.0	17.3	23.5	30.7	38.9	48.0
.5	00.50	02.0	04.5	08.0	12.5	18.0	24.5	32.0	40.5	50.0
.6	00.52	02.1	04.7	08.3	13.0	18.7	25.5	33.3	42.1	52.0
.7	00.54	02.2	04.9	08.6	13.5	19.4	26.5	34.6	43.7	54.0
.8	00.56	02.2	05.0	09.0	14.0	20.2	27.4	35.8	45.4	56.0
.9	00.58	02.3	05.2	09.3	14.5	20.9	28.4	37.1	47.0	58.0
3.0	0 00.60	0 02.4	0 05.4	0 09.6	0 15.0	0 21.6	0 29.4	0 38.4	0 48.6	1 00.0
.1	00.62	02.5	05.6	09.9	15.5	22.3	30.4	39.7	50.2	02.0
.2	00.64	02.6	05.8	10.2	16.0	23.0	31.4	41.0	51.8	04.0
.3	00.66	02.6	05.9	10.6	16.5	23.8	32.3	42.2	53.5	06.0
.4	00.68	02.7	06.1	10.9	17.0	24.5	33.3	43.5	55.1	08.0
.5	00.70	02.8	06.3	11.2	17.5	25.2	34.3	44.8	56.7	10.0
.6	00.72	02.9	06.5	11.5	18.0	25.9	35.3	46.1	58.3	12.0
.7	00.74	03.0	06.7	11.8	18.5	26.6	36.3	47.4	59.9	14.0
.8	00.76	03.0	06.8	12.2	19.0	27.4	37.2	48.6	1 01.6	16.0
.9	00.78	03.1	07.0	12.5	19.5	28.1	38.2	49.9	03.2	18.0
4.0	0 00.80	0 03.2	0 07.2	0 12.8	0 20.0	0 28.8	0 39.2	0 51.2	1 04.8	1 20.0
.1	00.82	03.3	07.4	13.1	20.5	29.5	40.2	52.5	06.4	22.0
.2	00.84	03.4	07.6	13.4	21.0	30.2	41.2	53.8	08.0	24.0
.3	00.86	03.4	07.7	13.8	21.5	31.0	42.1	55.0	09.7	26.0
.4	00.88	03.5	07.9	14.1	22.0	31.7	43.1	56.3	11.3	28.0
.5	00.90	03.6	08.1	14.4	22.5	32.4	44.1	57.6	12.9	30.0
.6	00.92	03.7	08.3	14.7	23.0	33.1	45.1	58.9	14.5	32.0
.7	00.94	03.8	08.5	15.0	23.5	33.8	46.1	1 00.2	16.1	34.0
.8	00.96	03.8	08.6	15.4	24.0	34.6	47.0	01.4	17.8	36.0
.9	00.98	03.9	08.8	15.7	24.5	35.3	48.0	02.7	19.4	38.0
5.0	0 01.00	0 04.0	0 09.0	0 16.0	0 25.0	0 36.0	0 49.0	1 04.0	1 21.0	1 40.0
.1	01.02	04.1	09.2	16.3	25.5	36.7	50.0	05.3	22.6	42.0
.2	01.04	04.2	09.4	16.6	26.0	37.4	51.0	06.6	24.2	44.0
.3	01.06	04.2	09.5	17.0	26.5	38.2	51.9	07.8	25.9	46.0
.4	01.08	04.3	09.7	17.3	27.0	38.9	52.9	09.1	27.5	48.0
.5	01.10	04.4	09.9	17.6	27.5	39.6	53.9	10.4	29.1	50.0
.6	01.12	04.5	10.1	17.9	28.0	40.3	54.9	11.7	30.7	52.0
.7	01.14	04.6	10.3	18.2	28.5	41.0	55.9	13.0	32.3	54.0
.8	01.16	04.6	10.4	18.6	29.0	41.8	56.8	14.2	34.0	56.0
.9	01.18	04.7	10.6	18.9	29.5	42.5	57.8	15.5	35.3	58.0
6.0	0 01.20	0 04.8	0 10.8	0 19.2	0 30.0	0 43.2	0 58.8	1 16.8	1 37.2	2 00.0

SPIRAL. TRANSIT AT S

S	1	2	3	4	5	6	7	8	9	10
6.1°	0° 01.22'	0° 04.9'	0° 11.0'	0° 19.5'	0° 30.5'	0° 43.9'	0° 59.8'	1° 18.1'	1° 38.8'	2° 02.0'
.2	01.24	05.0	11.2	19.8	31.0	44.6	1 00.8	19.4	40.4	04.0
.3	01.26	05.0	11.3	20.2	31.5	45.4	01.7	20.6	42.1	06.0
.4	01.28	05.1	11.5	20.5	32.0	46.1	02.7	21.9	43.7	08.0
.5	01.30	05.2	11.7	20.8	32.5	46.8	03.7	23.2	45.3	10.0
.6	01.32	05.3	11.9	21.1	33.0	47.5	04.7	24.5	46.9	12.0
.7	01.34	05.4	12.1	21.4	33.5	48.2	05.7	25.8	48.5	14.0
.8	01.36	05.4	12.2	21.8	34.0	49.0	06.6	27.0	50.2	16.0
.9	01.38	05.5	12.4	22.1	34.5	49.7	07.6	28.3	51.8	18.0
7.0	0 01.40	0 05.6	0 12.6	0 22.4	0 35.0	0 50.4	1 08.6	1 29.6	1 53.4	2 20.0
.1	01.42	05.7	12.8	22.7	35.5	51.1	09.6	30.9	55.0	22.0
.2	01.44	05.8	13.0	23.0	36.0	51.8	10.6	32.2	56.6	24.0
.3	01.46	05.8	13.1	23.4	36.5	52.6	11.5	33.4	58.3	26.0
.4	01.48	05.9	13.3	23.7	37.0	53.3	12.5	34.7	59.9	28.0
.5	01.50	06.0	13.5	24.0	37.5	54.0	13.5	36.0	2 01.5	30.0
.6	01.52	06.1	13.7	24.3	38.0	54.7	14.5	37.3	03.1	32.0
.7	01.54	06.2	13.9	24.6	38.5	55.4	15.5	38.6	04.7	34.0
.8	01.56	06.2	14.0	25.0	39.0	56.2	16.4	39.8	06.4	36.0
.9	01.58	06.3	14.2	25.3	39.5	56.9	17.4	41.1	08.0	38.0
8.0	0 01.60	0 06.4	0 14.4	0 25.6	0 40.0	0 57.6	1 18.4	1 42.4	2 09.6	2 40.0
.1	01.62	06.5	14.6	25.9	40.5	58.3	19.4	43.7	11.2	42.0
.2	01.64	06.6	14.8	26.2	41.0	59.0	20.4	45.0	12.8	44.0
.3	01.66	06.6	14.9	26.6	41.5	59.8	21.3	46.2	14.5	46.0
.4	01.68	06.7	15.1	26.9	42.0	1 00.5	22.3	47.5	16.1	48.0
.5	01.70	06.8	15.3	27.2	42.5	01.2	23.3	48.8	17.7	50.0
.6	01.72	06.9	15.5	27.5	43.0	01.9	24.3	50.1	19.3	52.0
.7	01.74	07.0	15.7	27.8	43.5	02.6	25.3	51.4	20.9	54.0
.8	01.76	07.0	15.8	28.2	44.0	03.4	26.2	52.6	22.6	56.0
.9	01.78	07.1	16.0	28.5	44.5	04.1	27.2	53.9	24.2	58.0
9.0	0 01.80	0 07.2	0 16.2	0 28.8	0 45.0	1 04.8	1 28.2	1 55.2	2 25.8	3 00.0
.1	01.82	07.3	16.4	29.1	45.5	05.5	29.2	56.5	27.4	02.0
.2	01.84	07.4	16.6	29.4	46.0	06.2	30.2	57.8	29.0	04.0
.3	01.86	07.4	16.7	29.8	46.5	07.0	31.1	59.0	30.7	06.0
.4	01.88	07.5	16.9	30.1	47.0	07.7	32.1	2 00.3	32.3	08.0
.5	01.90	07.6	17.1	30.4	47.5	08.4	33.1	01.6	33.9	10.0
.6	01.92	07.7	17.3	30.7	48.0	09.1	34.1	02.9	35.5	12.0
.7	01.94	07.8	17.5	31.0	48.5	09.8	35.1	04.2	37.1	14.0
.8	01.96	07.8	17.6	31.4	49.0	10.6	36.0	05.4	38.8	16.0
.9	01.98	07.9	17.8	31.7	49.5	11.3	37.0	06.7	40.4	18.0
10.0	0 02.00	0 08.0	0 18.0	0 32.0	0 50.0	1 12.0	1 38.0	2 08.0	2 42.0	3 20.0
.1	02.02	08.1	18.2	32.3	50.5	12.7	39.0	09.3	43.6	21.9
.2	02.04	08.2	18.4	32.6	51.0	13.4	40.0	10.6	45.2	23.9
.3	02.06	08.2	18.5	33.0	51.5	14.2	40.9	11.8	46.8	25.9
.4	02.08	08.3	18.7	33.3	52.0	14.9	41.9	13.1	48.5	27.9
.5	02.10	08.4	18.9	33.6	52.5	15.6	42.9	14.4	50.1	29.9
.6	02.12	08.5	19.1	33.9	53.0	16.3	43.9	15.7	51.7	31.9
.7	02.14	08.6	19.3	34.2	53.5	17.0	44.9	17.0	53.3	33.9
.8	02.16	08.6	19.4	34.6	54.0	17.8	45.8	18.2	54.9	35.9
.9	02.18	08.7	19.6	34.9	54.5	18.5	46.8	19.5	56.6	37.9
11.0	0 02.20	0 08.8	0 19.8	0 35.2	0 55.0	1 19.2	1 47.8	2 20.8	2 58.2	3 39.9
.1	02.22	08.9	20.0	35.5	55.5	19.9	48.8	22.1	59.8	41.9
.2	02.24	09.0	20.2	35.8	56.0	20.6	49.8	23.4	3 01.4	43.9
.3	02.26	09.0	20.3	36.2	56.5	21.4	50.7	24.6	03.0	45.9
.4	02.28	09.1	20.5	36.5	57.0	22.1	51.7	25.9	04.7	47.9
.5	02.30	09.2	20.7	36.8	57.5	22.8	52.7	27.2	06.3	49.9
.6	02.32	09.3	20.9	37.1	58.0	23.5	53.7	28.5	07.9	51.9
.7	02.34	09.4	21.1	37.4	58.5	24.2	54.7	29.7	09.5	53.9
.8	02.36	09.4	21.2	37.8	59.0	25.0	55.6	31.0	11.1	55.9
.9	02.38	09.5	21.4	38.1	59.5	25.7	56.6	32.3	12.7	57.9
12.0	0 02.40	0 09.6	0 21.6	0 38.4	1 00.0	1 26.4	1 57.6	2 33.6	3 14.4	3 59.9

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD
 SPIRAL. TRANSIT AT S

S	1	2	3	4	5	6	7	8	9	10
12.1°	0° 02.42'	0° 09.7'	0° 21.8'	0° 38.7'	1° 00.5'	1° 27.1'	1° 58.6'	2° 34.9'	3° 16.0'	4° 01.9'
.2	02.44	09.8	22.0	39.0	01.0	27.8	59.5	36.1	17.6	03.9
.3	02.46	09.8	22.1	39.4	01.5	28.6	2 00.5	37.4	19.2	05.9
.4	02.48	09.9	22.3	39.7	02.0	29.3	01.5	38.7	20.8	07.9
.5	02.50	10.0	22.5	40.0	02.5	30.0	02.5	40.0	22.5	09.9
.6	02.52	10.1	22.7	40.3	03.0	30.7	03.5	41.3	24.1	11.9
.7	02.54	10.2	22.9	40.6	03.5	31.4	04.4	42.5	25.7	13.9
.8	02.56	10.2	23.0	41.0	04.0	32.2	05.4	43.8	27.3	15.9
.9	02.58	10.3	23.2	41.3	04.5	32.9	06.4	45.1	28.9	17.9
13.0	0 02.60	0 10.4	0 23.4	0 41.6	1 05.0	1 33.6	2 07.4	2 46.4	3 30.5	4 19.9
.1	02.62	10.5	23.6	41.9	05.5	34.3	08.4	47.7	32.2	21.9
.2	02.64	10.6	23.8	42.2	06.0	35.0	09.3	48.9	33.8	23.9
.3	02.66	10.6	23.9	42.6	06.5	35.8	10.3	50.2	35.4	25.9
.4	02.68	10.7	24.1	42.9	07.0	36.5	11.3	51.5	37.0	27.9
.5	02.70	10.8	24.3	43.2	07.5	37.2	12.3	52.8	38.6	29.9
.6	02.72	10.9	24.5	43.5	08.0	37.9	13.3	54.0	40.3	31.9
.7	02.74	11.0	24.7	43.8	08.5	38.6	14.2	55.3	41.9	33.9
.8	02.76	11.0	24.8	44.2	09.0	39.4	15.2	56.6	43.5	35.9
.9	02.78	11.1	25.0	44.5	09.5	40.1	16.2	57.9	45.1	37.9
14.0	0 02.80	0 11.2	0 25.2	0 44.8	1 10.0	1 40.8	2 17.2	2 59.2	3 46.7	4 39.9
.1	02.82	11.3	25.4	45.1	10.5	41.5	18.2	3 00.4	48.4	41.9
.2	02.84	11.4	25.6	45.4	11.0	42.2	19.1	01.7	50.0	43.9
.3	02.86	11.4	25.7	45.8	11.5	43.0	20.1	03.0	51.6	45.9
.4	02.88	11.5	25.9	46.1	12.0	43.7	21.1	04.3	53.2	47.9
.5	02.90	11.6	26.1	46.4	12.5	44.4	22.1	05.6	54.8	49.9
.6	02.92	11.7	26.3	46.7	13.0	45.1	23.1	06.8	56.4	51.9
.7	02.94	11.8	26.5	47.0	13.5	45.8	24.0	08.1	58.1	53.9
.8	02.96	11.8	26.6	47.4	14.0	46.6	25.0	09.4	59.7	55.8
.9	02.98	11.9	26.8	47.7	14.5	47.3	26.0	10.7	4 01.3	57.8
15.0	0 03.00	0 12.0	0 27.0	0 48.0	1 15.0	1 48.0	2 27.0	3 12.0	4 02.9	4 59.8
.1	03.02	12.1	27.2	48.3	15.5	48.7	28.0	13.2	04.5	5 01.8
.2	03.04	12.2	27.4	48.6	16.0	49.4	28.9	14.5	06.1	03.8
.3	03.06	12.2	27.5	49.0	16.5	50.2	29.9	15.8	07.8	05.8
.4	03.08	12.3	27.7	49.3	17.0	50.9	30.9	17.1	09.4	07.8
.5	03.10	12.4	27.9	49.6	17.5	51.6	31.9	18.4	11.0	09.8
.6	03.12	12.5	28.1	49.9	18.0	52.3	32.9	19.6	12.6	11.8
.7	03.14	12.6	28.3	50.2	18.5	53.0	33.8	20.9	14.2	13.8
.8	03.16	12.6	28.4	50.6	19.0	53.7	34.8	22.2	15.9	15.8
.9	03.18	12.7	28.6	50.9	19.5	54.5	35.8	23.5	17.5	17.8
16.0	0 03.20	0 12.8	0 28.8	0 51.2	1 20.0	1 55.2	2 36.8	3 24.8	19.1	19.8
.1	03.22	12.9	29.0	51.5	20.5	55.9	37.8	26.0	20.7	21.8
.2	03.24	13.0	29.2	51.8	21.0	56.6	38.7	27.3	22.3	23.8
.3	03.26	13.0	29.3	52.2	21.5	57.3	39.7	28.6	23.9	25.8
.4	03.28	13.1	29.5	52.5	22.0	58.1	40.7	29.9	25.6	27.8
.5	03.30	13.2	29.7	52.8	22.5	58.8	41.7	31.1	27.2	29.8
.6	03.32	13.3	29.9	53.1	23.0	59.5	42.7	32.4	28.8	31.8
.7	03.34	13.4	30.1	53.4	23.5	2 00.2	43.6	33.7	30.4	33.8
.8	03.36	13.4	30.2	53.8	24.0	00.9	44.6	35.0	32.0	35.8
.9	03.38	13.5	30.4	54.1	24.5	01.7	45.6	36.3	33.6	37.8
17.0	0 03.40	0 13.6	0 30.6	0 54.4	1 25.0	2 02.4	2 46.6	3 37.5	4 35.3	5 39.8
.1	03.42	13.7	30.8	54.7	25.5	03.1	47.5	38.8	36.9	41.8
.2	03.44	13.8	31.0	55.0	26.0	03.8	48.5	40.1	38.5	43.7
.3	03.46	13.8	31.1	55.4	26.5	04.5	49.5	41.4	40.1	45.7
.4	03.48	13.9	31.3	55.7	27.0	05.3	50.5	42.7	41.7	47.7
.5	03.50	14.0	31.5	56.0	27.5	06.0	51.5	43.9	43.4	49.7
.6	03.52	14.1	31.7	56.3	28.0	06.7	52.4	45.2	45.0	51.7
.7	03.54	14.2	31.9	56.6	28.5	07.4	53.4	46.5	46.6	53.7
.8	03.56	14.2	32.0	57.0	29.0	08.1	54.4	47.8	48.2	55.7
.9	03.58	14.3	32.2	57.3	29.5	08.9	55.4	49.0	49.8	57.7
18.0	0 03.60	0 14.4	0 32.4	0 57.6	1 30.0	2 09.6	2 56.4	3 50.3	4 51.5	5 59.7

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD SPIRAL. TRANSIT AT S 363

S	1	2	3	4	5	6	7	8	9	10
18.1°	0° 03.62'	0° 14.5'	0° 32.6'	0° 57.9'	1° 30.5'	2° 10.3'	3° 57.3'	4° 51.6'	5° 53.1'	6° 01.7'
.2	03.64	14.6	32.8	58.2	31.0	11.0	58.3	52.9	54.7	03.7
.3	03.66	14.6	32.9	58.6	31.5	11.7	59.3	54.2	56.3	05.7
.4	03.68	14.7	33.1	58.9	32.0	12.5	3 00.3	55.4	57.9	07.7
.5	03.70	14.8	33.3	59.2	32.5	13.2	01.3	56.7	59.5	09.7
.6	03.72	14.9	33.5	59.5	33.0	13.9	02.2	58.0	5 01.2	11.7
.7	03.74	15.0	33.7	59.8	33.5	14.6	03.2	59.3	02.8	13.7
.8	03.76	15.0	33.8	1 00.2	34.0	15.3	04.2	4 00.6	04.4	15.7
.9	03.78	15.1	34.0	00.5	34.5	16.1	05.2	01.8	06.0	17.7
19.0	0 03.80	0 15.2	0 34.2	1 00.8	1 35.0	2 16.8	3 06.2	4 03.1	5 07.6	6 19.7
.1	03.82	15.3	34.4	01.1	35.5	17.5	07.1	04.4	09.2	21.7
.2	03.84	15.4	34.6	01.4	36.0	18.2	08.1	05.7	10.9	23.7
.3	03.86	15.4	34.7	01.8	36.5	18.9	09.1	06.9	12.5	25.6
.4	03.88	15.5	34.9	02.1	37.0	19.7	10.1	08.2	14.1	27.6
.5	03.90	15.6	35.1	02.4	37.5	20.4	11.1	09.5	15.7	29.6
.6	03.92	15.7	35.3	02.7	38.0	21.1	12.0	10.8	17.3	31.6
.7	03.94	15.8	35.5	03.0	38.5	21.8	13.0	12.1	18.9	33.6
.8	03.96	15.8	35.6	03.4	39.0	22.5	14.0	13.3	20.6	35.6
.9	03.98	15.9	35.8	03.7	39.5	23.3	15.0	14.6	22.2	37.6
20.0	0 04.00	0 16.0	0 36.0	1 04.0	1 40.0	2 24.0	3 16.0	4 15.9	5 22.8	39.6
.2	04.04	16.2	36.4	04.6	41.0	25.4	17.9	18.5	27.0	43.6
.4	04.08	16.3	36.7	05.3	42.0	26.9	19.9	21.0	30.3	47.6
.6	04.12	16.5	37.1	05.9	43.0	28.3	21.8	23.6	33.5	51.6
.8	04.16	16.6	37.4	06.6	44.0	29.7	23.8	26.1	36.7	55.6
21.0	0 04.20	0 16.8	0 37.8	1 07.2	1 45.0	2 31.2	3 25.8	4 28.7	5 40.0	6 59.5
.2	04.24	17.0	38.2	07.8	46.0	32.6	27.7	31.2	43.2	7 03.5
.4	04.28	17.1	38.5	08.5	47.0	34.1	29.7	33.8	46.4	07.5
.6	04.32	17.3	38.9	09.1	48.0	35.5	31.6	36.4	49.7	11.5
.8	04.36	17.4	39.2	09.8	49.0	37.0	33.6	38.9	52.9	15.5
22.0	0 04.40	0 17.6	0 39.6	1 10.4	1 50.0	2 38.4	3 35.5	4 41.5	5 56.1	7 19.5
.2	04.44	17.8	40.0	11.0	51.0	39.8	37.5	44.0	59.3	23.5
.4	04.48	17.9	40.3	11.7	52.0	41.3	39.5	46.6	6 02.6	27.5
.6	04.52	18.1	40.7	12.3	53.0	42.7	41.4	49.1	05.8	31.4
.8	04.56	18.2	41.0	13.0	54.0	44.2	43.4	51.7	09.0	35.4
23.0	0 04.60	0 18.4	0 41.4	1 13.6	1 55.0	2 45.6	3 45.3	4 54.2	6 12.3	7 39.4
.2	04.64	18.6	41.8	14.2	56.0	47.0	47.3	56.8	15.5	43.4
.4	04.68	18.7	42.1	14.9	57.0	48.5	49.2	59.4	18.7	47.4
.6	04.72	18.9	42.5	15.5	58.0	49.9	51.2	5 01.9	22.0	51.4
.8	04.76	19.0	42.8	16.2	59.0	51.4	53.2	04.5	25.2	55.3
24.0	0 04.80	0 19.2	0 43.2	1 16.8	2 00.0	2 52.8	3 55.1	5 07.0	6 28.4	7 59.3
.2	04.84	19.4	43.6	17.4	01.0	54.2	57.1	09.6	31.7	8 03.2
.4	04.88	19.5	43.9	18.1	02.0	55.7	59.0	12.1	34.9	07.3
.6	04.92	19.7	44.3	18.7	03.0	57.1	4 01.0	14.7	38.1	11.2
.8	04.96	19.8	44.6	19.4	04.0	58.6	03.0	17.2	41.3	15.3
25.0	0 05.00	0 20.0	0 45.0	1 20.0	2 05.0	3 00.0	4 04.9	5 19.8	6 44.6	8 19.2
.2	05.04	20.2	45.4	20.6	06.0	01.4	06.9	22.4	47.8	23.2
.4	05.08	20.3	45.7	21.3	07.0	02.9	08.8	24.9	51.0	27.2
.6	05.12	20.5	46.1	21.9	08.0	04.3	10.8	27.5	54.3	31.2
.8	05.16	20.6	46.4	22.6	09.0	05.8	12.8	30.0	57.5	35.2
26.0	0 05.20	0 20.8	0 46.8	1 23.2	2 10.0	3 07.2	4 14.7	5 32.6	7 00.7	8 39.1
.2	05.24	21.0	47.2	23.8	11.0	08.6	16.7	35.1	04.0	43.1
.4	05.28	21.1	47.5	24.5	12.0	10.1	18.6	37.7	07.2	47.1
.6	05.32	21.3	47.9	25.1	13.0	11.5	20.6	40.2	10.4	51.1
.8	05.36	21.4	48.2	25.8	14.0	13.0	22.5	42.8	13.7	55.1
27.0	0 05.40	0 21.6	0 48.6	1 26.4	2 15.0	3 14.4	4 24.5	5 45.4	7 16.9	8 59.0
.2	05.44	21.8	49.0	27.0	16.0	15.8	26.5	47.9	20.1	9 03.0
.4	05.48	21.9	49.3	27.7	17.0	17.3	28.4	50.5	23.3	07.0
.6	05.52	22.1	49.7	28.3	18.0	18.7	30.4	53.0	26.6	11.0
.8	05.56	22.2	50.0	29.0	19.0	20.1	32.3	55.6	29.8	14.9
28.0	0 05.60	0 22.4	0 50.4	1 29.6	2 20.0	3 21.5	4 34.3	5 58.1	7 33.0	9 18.9

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD
 SPIRAL. TRANSIT AT S

S	1	2	3	4	5	6	7	8	9	10
28.2°	0° 05.64'	0° 22.6'	0° 50.8'	1° 30.2'	2° 21.0'	3° 23.0'	4° 36.2'	6° 00.7'	7° 36.3'	9° 22.9'
.4	05.68	22.7	51.1	30.9	22.0	24.4	38.2	03.2	39.5	26.9
.6	05.72	22.9	51.5	31.5	23.0	25.9	40.2	05.8	42.7	30.9
.8	05.76	23.0	51.8	32.2	24.0	27.3	42.1	08.3	45.9	34.8
29.0	0 05.80	0 23.2	0 52.2	1 32.8	2 25.0	3 28.8	4 44.1	6 10.9	7 49.2	9 38.8
.2	05.84	23.4	52.6	33.4	26.0	30.2	46.0	13.4	52.4	42.8
.4	05.88	23.5	52.9	34.1	27.0	31.6	48.0	16.0	55.6	46.8
.6	05.92	23.7	53.3	34.7	28.0	33.1	49.9	18.6	58.8	50.7
.8	05.96	23.8	53.6	35.4	29.0	34.5	51.9	21.1	62.1	54.7
30.0	0 06.00	0 24.0	0 54.0	1 36.0	2 30.0	3 35.9	4 53.9	6 23.7	8 05.3	9 58.7
.2	06.04	24.2	54.4	36.5	31.0	37.4	55.8	26.2	08.5	10 02.6
.4	06.08	24.3	54.7	37.3	32.0	38.8	57.8	28.8	11.7	06.6
.6	06.12	24.5	55.1	37.9	33.0	40.3	59.7	31.3	15.0	10.6
.8	06.16	24.6	55.4	38.6	34.0	41.7	61.7	33.9	18.2	14.6
31.0	0 06.20	0 24.8	0 55.8	1 39.2	2 35.0	3 43.1	5 03.6	6 36.4	8 21.4	10 18.5
.2	06.24	25.0	56.2	39.8	36.0	44.6	65.6	39.0	24.6	22.5
.4	06.28	25.1	56.5	40.5	37.0	46.0	67.5	41.5	27.9	26.5
.6	06.32	25.3	56.9	41.1	38.0	47.5	69.5	44.1	31.1	30.4
.8	06.36	25.4	57.2	41.8	39.0	48.9	71.5	46.6	34.3	34.4
32.0	0 06.40	0 25.6	0 57.6	1 42.4	2 40.0	3 50.3	5 13.4	6 49.2	8 37.5	10 38.4
.2	06.44	25.8	58.0	43.0	41.0	51.8	75.4	51.7	40.8	42.4
.4	06.48	25.9	58.3	43.7	42.0	53.2	77.3	54.3	44.0	46.3
.6	06.52	26.1	58.7	44.3	43.0	54.7	79.3	56.8	47.2	50.3
.8	06.56	26.2	59.0	45.0	44.0	56.1	81.2	59.4	50.4	54.3
33.0	0 06.60	0 26.4	0 59.4	1 45.6	2 45.0	3 57.5	5 23.2	7 01.9	8 53.7	10 58.2
.2	06.64	26.6	59.8	46.2	46.0	59.0	83.1	64.5	56.9	11 02.2
.4	06.68	26.7	1 00.1	46.9	47.0	60.4	85.1	67.0	60.1	06.2
.6	06.72	26.9	00.5	47.5	48.0	61.8	87.1	69.6	63.3	10.1
.8	06.76	27.0	00.8	48.2	49.0	63.3	89.1	72.1	66.5	14.1
34.0	0 06.80	0 27.2	1 01.2	1 48.8	2 50.0	4 04.7	5 33.0	7 14.7	9 09.8	11 18.1
.2	06.84	27.4	01.6	49.4	51.0	66.2	91.9	77.2	70.0	22.0
.4	06.88	27.5	01.9	50.1	52.0	67.6	93.9	79.8	73.2	26.0
.6	06.92	27.7	02.3	50.7	53.0	69.0	95.8	82.4	76.4	30.0
.8	06.96	27.8	02.6	51.4	54.0	70.5	97.8	84.9	79.6	33.9
35.0	0 07.00	0 28.0	1 03.0	1 52.0	2 55.0	4 11.9	5 42.8	7 27.5	9 25.9	11 37.9
.2	07.04	28.2	03.4	52.6	56.0	73.3	99.7	87.0	83.0	41.8
.4	07.08	28.3	03.7	53.3	57.0	74.8	101.7	89.6	86.2	45.8
.6	07.12	28.5	04.1	53.9	58.0	76.2	103.7	92.1	89.4	49.8
.8	07.16	28.6	04.4	54.6	59.0	77.7	105.7	94.6	92.6	53.7
36.0	0 07.20	0 28.8	1 04.8	1 55.2	3 00.0	4 19.1	5 52.5	7 40.2	9 42.0	11 57.7
.2	07.24	29.0	05.2	55.8	61.0	80.5	107.7	97.2	95.8	12 01.7
.4	07.28	29.1	05.5	56.5	62.0	82.0	109.7	99.8	99.0	05.6
.6	07.32	29.3	05.9	57.1	63.0	83.4	111.7	102.4	102.2	09.6
.8	07.36	29.4	06.2	57.8	64.0	84.8	113.7	104.9	105.4	13.5
37.0	0 07.40	0 29.6	1 06.6	1 58.4	3 05.0	4 26.3	6 02.3	7 52.9	9 58.1	12 17.5
.2	07.44	29.8	07.0	59.0	65.0	86.7	115.7	107.5	108.0	21.5
.4	07.48	29.9	07.3	59.7	66.0	88.2	117.7	110.0	111.0	25.4
.6	07.52	30.1	07.7	60.3	67.0	89.6	119.7	112.6	114.0	29.4
.8	07.56	30.2	08.0	61.0	68.0	91.0	121.7	115.1	117.0	33.3
38.0	0 07.60	0 30.4	1 08.4	2 01.6	3 10.0	4 33.5	6 12.1	8 05.7	10 14.2	12 37.3
.2	07.64	30.6	08.8	62.2	70.0	93.5	123.7	117.7	120.0	41.2
.4	07.68	30.7	09.1	62.9	71.0	95.0	125.7	120.3	123.2	45.2
.6	07.72	30.9	09.5	63.5	72.0	96.4	127.7	122.9	126.4	49.2
.8	07.76	31.0	09.8	64.2	73.0	97.9	129.7	125.4	129.6	53.1
39.0	0 07.80	0 31.2	1 10.2	2 04.8	3 15.0	4 40.7	6 21.9	8 18.4	10 30.2	12 57.1
.2	07.84	31.4	10.6	65.4	74.0	99.9	131.7	128.0	132.0	61.0
.4	07.88	31.5	10.9	66.1	75.0	101.4	133.7	130.6	135.2	65.0
.6	07.92	31.7	11.3	66.7	76.0	102.9	135.7	133.2	138.4	68.9
.8	07.96	31.8	11.6	67.4	77.0	104.4	137.7	135.8	141.6	72.9
40.0	0 08.00	0 32.0	1 12.0	2 08.0	3 20.0	4 47.9	6 31.6	8 31.2	10 46.3	13 16.8

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD SPIRAL. TRANSIT AT *S* 365

<i>S</i>	1	2	3	4	5	6	7	8	9	16
40.2°	0° 08.04'	0° 32.2'	1° 12.4'	2° 08.6'	3° 20.9'	4° 49.3'	6° 33.6'	8° 33.7'	10° 49.5'	13° 20.8'
.4	08.08	32.3	12.7	09.3	21.9	50.7	35.5	36.3	52.8	24.7
.6	08.12	32.5	13.1	09.9	22.9	52.2	37.5	38.8	56.0	28.7
.8	08.16	32.6	13.4	10.6	23.9	53.6	39.5	41.4	59.2	32.6
41.0	0 08.20	0 32.8	1 13.8	2 11.2	3 24.9	4 55.0	6 41.4	8 43.9	11 02.4	13 36.6
.2	08.24	33.0	14.2	11.8	25.9	56.5	43.4	46.5	05.6	40.5
.4	08.28	33.1	14.5	12.5	26.9	57.9	45.3	49.0	08.8	44.5
.6	08.32	33.3	14.9	13.1	27.9	59.4	47.3	51.6	12.0	48.4
.8	08.36	33.4	15.2	13.8	28.9	60.8	49.2	54.1	15.2	52.4
42.0	0 08.40	0 33.6	1 15.6	2 14.4	3 29.9	5 02.2	6 51.2	8 56.6	11 18.4	13 56.3
.2	08.44	33.8	16.0	15.0	30.9	63.7	53.1	59.2	21.7	14 00.3
.4	08.48	33.9	16.3	15.7	31.9	65.1	55.1	61.7	24.9	04.2
.6	08.52	34.1	16.7	16.3	32.9	66.5	57.0	64.3	28.1	08.2
.8	08.56	34.2	17.0	17.0	33.9	68.0	59.0	66.8	31.3	12.1
43.0	0 08.60	0 34.4	1 17.4	2 17.6	3 34.9	5 09.4	7 01.0	9 09.4	11 34.5	16.1
.2	08.64	34.6	17.8	18.2	35.9	10.9	02.9	11.9	37.7	20.0
.4	08.68	34.7	18.1	18.9	36.9	12.3	04.9	14.5	40.9	24.0
.6	08.72	34.9	18.5	19.5	37.9	13.7	06.8	17.0	44.1	27.9
.8	08.76	35.0	18.8	20.2	38.9	15.2	08.8	19.5	47.4	31.8
44.0	0 08.80	0 35.2	1 19.2	2 20.8	3 39.9	5 16.6	7 10.7	9 22.1	11 50.6	14 35.8
.2	08.84	35.4	19.6	21.4	40.9	18.0	12.7	24.6	53.8	39.7
.4	08.88	35.5	19.9	22.1	41.9	19.5	14.6	27.2	57.0	43.7
.6	08.92	35.7	20.3	22.7	42.9	20.9	16.6	29.7	12 00.2	47.6
.8	08.96	35.8	20.6	23.4	43.9	22.4	18.5	32.3	03.4	51.6
45.0	0 09.00	0 36.0	1 21.0	2 24.0	3 44.9	5 23.8	7 20.5	9 34.8	12 06.6	14 55.5

TABLE XLVI.—COEFFICIENTS FOR DEFLECTIONS FROM LOCAL TANGENT AT ANY POINT

Deflection Angle to Chord-point Number.	Transit at Chord-point Number.										
	0 T.S.	1	2	3	4	5	6	7	8	9	10 S.C.
0 T.S.	0	2	8	18	32	50	72	98	128	162	200
1	1	0	5	14	27	44	65	90	119	152	189
2	4	4	0	8	20	36	56	80	108	140	176
3	9	10	7	0	11	26	45	68	95	126	161
4	16	18	16	10	0	14	32	54	80	110	144
5	25	28	27	22	13	0	17	38	63	92	125
6	36	40	40	36	28	16	0	20	44	72	104
7	49	54	55	52	45	34	19	0	23	50	81
8	64	70	72	70	64	54	40	22	0	26	56
9	81	88	91	90	85	76	63	46	25	0	29
10 S.C.	100	108	112	112	108	100	88	72	52	28	0

TABLE XLVII.—CORRECTIONS IN MINUTES
 FOR LARGE DEFLECTIONS

$$\text{Eq. (H) } i = \frac{S}{3} \pm \text{correction}$$

Number of point from position of transit

<i>S</i>	5	6	7	8	9	10	<i>S</i>
7°					.00	.01	7°
8					.01	.01	8
9					.01	.02	9
10				.00	.02	.03	10
11				.01	.03	.04	11
12				.01	.04	.06	12
13				.02	.05	.09	13
14				.02	.06	.12	14
15			.00	.03	.08	.15	15
16			.01	.04	.10	.19	16
17			.01	.05	.12	.24	17
18			.02	.07	.14	.29	18
19			.02	.08	.17	.34	19
20			.03	.10	.20	.40	20
21			.03	.12	.24	.47	21
22			.04	.13	.27	.54	22
23			.05	.15	.32	.62	23
24		.00	.06	.18	.36	.70	24
25		.01	.08	.20	.41	.79	25
26		.02	.09	.22	.47	.88	26
27		.02	.10	.25	.52	.98	27
28		.03	.11	.28	.58	1.09	28
29		.04	.13	.31	.64	1.21	29
30		.05	.15	.34	.71	1.34	30
31		.06	.16	.37	.78	1.47	31
32		.07	.18	.41	.86	1.62	32
33		.08	.20	.45	.94	1.77	33
34		.09	.22	.49	1.02	1.93	34
35	.00	.10	.25	.54	1.11	2.11	35
36	.01	.11	.27	.59	1.20	2.29	36
37	.01	.12	.29	.64	1.30	2.49	37
38	.02	.13	.33	.70	1.41	2.70	38
39	.03	.15	.35	.76	1.53	2.92	39
40	.04	.16	.38	.83	1.65	3.15	40
41	.05	.17	.42	.90	1.78	3.40	41
42	.06	.19	.46	.98	1.93	3.66	42
43	.07	.20	.50	1.06	2.08	3.93	43
44	.09	.22	.55	1.15	2.24	4.23	44
45	.10	.25	.59	1.25	2.42	4.54	45
<i>S</i>	5	6	7	8	9	10	<i>S</i>

TABLE XLVIII.—SPIRAL PARTS FOR 1° CURVE 367

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	0.3°	30.00	0.03	60.00	0.10	60.00	40.00	20.00
80	0.4	40.00	0.05	80.00	0.19	80.00	53.33	26.67
100	0.5	50.00	0.07	100.00	0.29	100.00	66.67	33.33
120	0.6	60.00	0.10	120.00	0.42	120.00	80.00	40.00
140	0.7	70.00	0.14	140.00	0.57	140.00	93.33	46.67
160	0.8	80.00	0.19	160.00	0.74	160.00	106.67	53.33
180	0.9	90.00	0.24	180.00	0.94	180.00	120.00	60.00
200	1.0	100.00	0.29	199.99	1.16	200.00	133.34	66.67
220	1.1	110.00	0.35	219.99	1.41	220.00	146.67	73.34
240	1.2	120.00	0.42	239.99	1.68	240.00	160.00	80.00
260	1.3	130.00	0.49	259.99	1.97	259.99	173.34	86.67
280	1.4	140.00	0.57	279.98	2.28	279.99	186.67	93.34
300	1.5	149.99	0.65	299.98	2.62	299.99	200.01	100.01
320	1.6	159.99	0.74	319.98	2.98	319.99	213.34	106.67
340	1.7	169.99	0.84	339.97	3.36	339.99	226.68	113.33
360	1.8	179.99	0.94	359.97	3.77	359.98	240.01	120.00
380	1.9	189.99	1.05	379.96	4.20	379.98	253.34	126.67
400	2.0	199.99	1.16	399.95	4.65	399.98	266.68	133.35
420	2.1	209.99	1.28	419.94	5.13	419.98	280.02	140.02
440	2.2	219.99	1.41	439.94	5.63	439.97	293.36	146.69
460	2.3	229.99	1.54	459.93	6.15	459.97	306.69	153.36
480	2.4	239.98	1.68	479.92	6.70	479.96	320.03	160.03
500	2.5	249.98	1.82	499.91	7.27	499.96	333.37	166.70

SPIRAL PARTS FOR 1° 30' CURVE

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	0.45°	30.00	0.04	60.00	0.16	60.00	40.00	20.00
80	0.60	40.00	0.07	80.00	0.28	80.00	53.33	26.67
100	0.75	50.00	0.11	100.00	0.44	100.00	66.67	33.33
120	0.90	60.00	0.16	120.00	0.63	120.00	80.00	40.00
140	1.05	70.00	0.21	140.00	0.86	140.00	93.33	46.67
160	1.20	80.00	0.28	159.99	1.12	160.00	106.67	53.33
180	1.35	90.00	0.35	179.99	1.41	180.00	120.00	60.00
200	1.50	99.99	0.44	199.99	1.75	199.99	133.34	66.67
220	1.65	109.99	0.53	219.98	2.11	219.99	146.67	73.34
240	1.80	119.99	0.63	239.98	2.51	239.99	160.01	80.01
260	1.95	129.99	0.74	259.97	2.95	259.99	173.35	86.68
280	2.10	139.99	0.86	279.96	3.42	279.98	186.68	93.35
300	2.25	149.99	0.98	299.95	3.93	299.98	200.01	100.01
320	2.40	159.99	1.12	319.94	4.47	319.98	213.35	106.68
340	2.55	169.98	1.26	339.93	5.04	339.97	226.69	113.35
360	2.70	179.98	1.41	359.92	5.65	359.97	240.03	120.03
380	2.85	189.98	1.58	379.91	6.30	379.96	253.37	126.70
400	3.00	199.98	1.75	399.89	6.98	399.95	266.71	133.37
420	3.15	209.97	1.92	419.87	7.70	419.94	280.04	140.04
440	3.30	219.97	2.11	439.86	8.45	439.94	293.38	146.71
460	3.45	229.97	2.31	459.83	9.23	459.93	306.72	153.39
480	3.60	239.96	2.51	479.81	10.05	479.92	320.07	160.06
500	3.75	249.96	2.73	499.79	10.90	499.91	333.41	166.74

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	0.6°	30.00	0.05	60.00	0.21	60.00	40.00	20.00
80	0.8	40.00	0.09	80.00	0.37	80.00	53.33	26.67
100	1.0	50.00	0.15	100.00	0.58	100.00	66.67	33.33
120	1.2	60.00	0.21	119.99	0.84	120.00	80.00	40.00
140	1.4	70.00	0.29	139.99	1.14	140.00	93.33	46.67
160	1.6	79.99	0.37	159.99	1.49	159.99	106.67	53.33
180	1.8	89.99	0.47	179.98	1.88	179.99	120.00	60.00
200	2.0	99.99	0.58	199.98	2.33	199.99	133.34	66.67
220	2.2	109.99	0.70	219.97	2.82	219.99	146.67	73.34
240	2.4	119.99	0.84	239.96	3.35	239.98	160.01	80.01
260	2.6	129.98	0.98	259.95	3.93	259.98	173.35	86.68
280	2.8	139.98	1.14	279.93	4.56	279.97	186.69	93.35
300	3.0	149.98	1.31	299.92	5.24	299.96	200.03	100.02
320	3.2	159.98	1.49	319.90	5.96	319.96	213.36	106.69
340	3.4	169.97	1.68	339.88	6.72	339.95	226.70	113.36
360	3.6	179.97	1.88	359.86	7.54	359.94	240.04	120.03
380	3.8	189.96	2.10	379.83	8.40	379.93	253.38	126.71
400	4.0	199.96	2.33	399.81	9.31	399.91	266.72	133.39
420	4.2	209.95	2.56	419.78	10.26	419.90	280.07	140.07
440	4.4	219.95	2.81	439.74	11.26	439.89	293.42	146.75
460	4.6	229.94	3.08	459.71	12.31	459.87	306.77	153.43
480	4.8	239.93	3.35	479.66	13.40	479.85	320.12	160.11
500	5.0	249.93	3.63	499.62	14.54	499.83	333.47	166.79

SPIRAL PARTS FOR 2° 30' CURVE

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	0.75°	30.00	0.07	60.00	0.26	60.00	40.00	20.00
80	1.00	40.00	0.12	80.00	0.47	80.00	53.33	26.67
100	1.25	50.00	0.18	100.00	0.73	100.00	66.67	33.33
120	1.50	59.99	0.26	119.99	1.05	120.00	80.00	40.00
140	1.75	69.99	0.36	139.99	1.43	139.99	93.33	46.67
160	2.00	79.99	0.47	159.98	1.86	159.99	106.67	53.34
180	2.25	89.99	0.59	179.97	2.36	179.99	120.01	60.00
200	2.50	99.99	0.73	199.96	2.91	199.93	133.35	66.68
220	2.75	109.98	0.88	219.95	3.52	219.98	146.68	73.35
240	3.00	119.98	1.05	239.93	4.19	239.97	160.02	80.02
260	3.25	129.98	1.23	259.92	4.91	259.96	173.36	86.69
280	3.50	139.97	1.42	279.90	5.70	279.95	186.70	93.37
300	3.75	149.97	1.64	299.87	6.54	299.94	200.05	100.04
320	4.00	159.96	1.86	319.84	7.44	319.93	213.39	106.72
340	4.25	169.96	2.10	339.81	8.40	339.92	226.73	113.40
360	4.50	179.95	2.36	359.78	9.42	359.90	240.08	120.07
380	4.75	189.94	2.62	379.74	10.50	379.89	253.42	126.75
400	5.00	199.93	2.91	399.70	11.63	399.87	266.77	133.43
420	5.25	209.93	3.21	419.65	12.82	419.85	280.12	140.11
440	5.50	219.92	3.52	439.60	14.07	439.82	293.48	146.80
460	5.75	229.91	3.84	459.54	15.38	459.80	306.84	153.49
480	6.00	239.90	4.19	479.48	16.74	479.77	320.19	160.17
500	6.25	249.88	4.54	499.41	18.17	499.74	333.54	166.86

TABLE XLVIII.—SPIRAL PARTS FOR 3° CURVE 369

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	0.9°	30.00	0.08	60.00	0.31	60.00	40.00	20.00
80	1.2	39.99	0.14	80.00	0.56	80.00	53.33	26.67
100	1.5	49.99	0.22	99.99	0.87	100.00	66.67	33.34
120	1.8	59.99	0.31	119.99	1.26	119.99	80.00	40.00
140	2.1	69.99	0.43	139.98	1.71	139.99	93.34	46.67
160	2.4	79.99	0.56	159.97	2.23	159.99	106.68	53.34
180	2.7	89.98	0.71	179.96	2.83	179.98	120.01	60.01
200	3.0	99.98	0.87	199.95	3.49	199.98	133.35	66.68
220	3.3	109.98	1.06	219.93	4.22	219.97	146.69	73.35
240	3.6	119.97	1.26	239.91	5.03	239.96	160.03	80.03
260	3.9	129.97	1.47	259.88	5.90	259.95	173.38	86.71
280	4.2	139.96	1.71	279.85	6.84	279.93	186.72	93.38
300	4.5	149.95	1.96	299.82	7.85	299.92	200.07	100.06
320	4.8	159.95	2.23	319.78	8.93	319.90	213.41	106.74
340	5.1	169.94	2.52	339.73	10.08	339.88	226.76	113.41
360	5.4	179.93	2.83	359.68	11.30	359.86	240.11	120.09
380	5.7	189.92	3.15	379.63	12.59	379.84	253.47	126.77
400	6.0	199.91	3.49	399.56	13.95	399.81	266.82	133.47
420	6.3	209.89	3.85	419.50	15.38	419.78	280.18	140.16
440	6.6	219.88	4.22	439.42	16.88	439.74	293.54	146.85
460	6.9	229.87	4.61	459.34	18.45	459.71	306.90	153.55
480	7.2	239.85	5.02	479.25	20.08	479.67	320.27	160.24
500	7.5	249.83	5.45	499.15	21.79	499.62	333.64	166.94

SPIRAL PARTS FOR 3° 30' CURVE

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	1.05	30.00	0.09	60.00	0.37	60.00	40.00	20.00
80	1.40	39.99	0.16	80.00	0.65	80.00	53.33	26.67
100	1.75	49.99	0.25	99.99	1.02	100.00	66.67	33.34
120	2.10	59.99	0.37	119.98	1.47	119.99	80.01	40.01
140	2.45	69.99	0.50	139.97	2.00	139.99	93.35	46.68
160	2.80	79.98	0.65	159.96	2.61	159.98	106.68	53.35
180	3.15	89.98	0.82	179.95	3.30	179.98	120.02	60.02
200	3.50	99.97	1.02	199.93	4.07	199.97	133.36	66.69
220	3.85	109.97	1.23	219.90	4.93	219.96	146.70	73.36
240	4.20	119.96	1.47	239.87	5.86	239.94	160.05	80.04
260	4.55	129.95	1.72	259.84	6.88	259.93	173.40	86.72
280	4.90	139.95	1.99	279.80	7.98	279.91	186.75	93.40
300	5.25	149.94	2.29	299.75	9.16	299.89	200.10	100.08
320	5.60	159.93	2.60	319.70	10.42	319.87	213.44	106.76
340	5.95	169.92	2.94	339.64	11.76	339.84	226.79	113.44
360	6.30	179.90	3.30	359.57	13.18	359.81	240.15	120.14
380	6.65	189.89	3.67	379.49	14.69	379.78	253.51	126.83
400	7.00	199.87	4.07	399.41	16.27	399.74	266.88	133.52
420	7.35	209.86	4.49	419.31	17.94	419.70	280.25	140.22
440	7.70	219.84	4.92	439.21	19.69	439.65	293.61	146.92
460	8.05	229.82	5.38	459.10	21.51	459.60	306.98	153.63
480	8.40	239.80	5.86	478.98	23.42	479.55	320.36	160.33
500	8.75	249.77	6.36	498.84	25.41	499.49	333.74	167.04

370 TABLE XLVIII.—SPIRAL PARTS FOR 4° CURVE

L	S	q	p	Y	X	C	U	V
60	1.2°	29.99	0.10	60.00	0.42	60.00	40.00	20.00
80	1.6	39.99	0.19	79.99	0.74	80.00	53.33	26.67
100	2.0	49.99	0.29	99.99	1.16	99.99	66.67	33.34
120	2.4	59.98	0.42	119.98	1.68	119.99	80.00	40.01
140	2.8	69.98	0.57	139.97	2.28	139.99	93.34	46.68
160	3.2	79.98	0.74	159.95	2.98	159.98	106.68	53.35
180	3.6	89.97	0.94	179.93	3.77	179.97	120.02	60.02
200	4.0	99.96	1.16	199.90	4.65	199.96	133.37	66.69
220	4.4	109.96	1.41	219.87	5.63	219.94	146.71	73.36
240	4.8	119.95	1.67	239.83	6.70	239.93	160.05	80.05
260	5.2	129.94	1.96	259.79	7.86	259.91	173.41	86.74
280	5.6	139.93	2.28	279.73	9.12	279.88	186.76	93.42
300	6.0	149.92	2.62	299.67	10.46	299.86	200.12	100.11
320	6.4	159.90	2.98	319.60	11.90	319.82	213.47	106.79
340	6.8	169.89	3.36	339.52	13.44	339.79	226.83	113.48
360	7.2	179.87	3.77	359.44	15.06	359.75	240.20	120.18
380	7.6	189.85	4.20	379.34	16.78	379.71	253.57	126.87
400	8.0	199.83	4.65	399.23	18.59	399.66	266.94	133.58
420	8.4	209.81	5.12	419.10	20.49	419.60	280.32	140.29
440	8.8	219.79	5.62	438.97	22.49	439.54	293.70	147.00
460	9.2	229.76	6.15	458.82	24.58	459.48	307.08	153.71
480	9.6	239.73	6.69	478.66	26.76	479.41	320.47	160.43
500	10.0	249.70	7.26	498.49	29.03	499.33	333.87	167.16

SPIRAL PARTS FOR 4° 30' CURVE

L	S	q	p	Y	X	C	U	V
60	1.35°	29.99	0.12	60.00	0.47	60.00	40.00	20.00
80	1.80	39.99	0.21	79.99	0.84	80.00	53.33	26.67
100	2.25	49.98	0.33	99.98	1.31	99.99	66.67	33.34
120	2.70	59.98	0.47	119.97	1.88	119.99	80.01	40.01
140	3.15	69.98	0.64	139.96	2.57	139.98	93.35	46.68
160	3.60	79.97	0.84	159.94	3.35	159.97	106.69	53.35
180	4.05	89.96	1.06	179.91	4.24	179.96	120.03	60.03
200	4.50	99.95	1.31	199.88	5.23	199.95	133.38	66.71
220	4.95	109.95	1.58	219.84	6.33	219.93	146.72	73.39
240	5.40	119.93	1.88	239.79	7.54	239.91	160.07	80.07
260	5.85	129.92	2.21	259.73	8.84	259.88	173.42	86.75
280	6.30	139.91	2.56	279.66	10.25	279.85	186.78	93.44
300	6.75	149.89	2.94	299.59	11.77	299.82	200.14	100.13
320	7.20	159.88	3.35	319.50	13.39	319.78	213.51	106.83
340	7.65	169.86	3.78	339.40	15.11	339.73	226.88	113.53
360	8.10	179.84	4.23	359.29	16.94	359.68	240.25	120.23
380	8.55	189.81	4.72	379.16	18.87	379.63	253.63	126.94
400	9.00	199.79	5.23	399.02	20.91	399.57	267.01	133.65
420	9.45	209.76	5.76	418.87	23.05	419.50	280.40	140.37
440	9.90	219.73	6.32	438.70	25.29	439.42	293.80	147.09
460	10.35	229.70	6.91	458.51	27.63	459.34	307.20	153.81
480	10.80	239.66	7.53	478.31	30.08	479.25	320.60	160.55
500	11.25	249.63	8.17	498.09	32.64	499.15	334.01	167.29

TABLE XLVIII.—SPIRAL PARTS FOR 5° CURVE 371

L	S	q	p	Y	X	C	U	V
60	1.5°	29.99	0.13	60.00	0.52	60.00	40.00	20.00
80	2.0	39.99	0.23	79.99	0.93	80.00	53.33	26.67
100	2.5	49.98	0.36	99.98	1.45	99.99	66.67	33.34
120	3.0	59.98	0.52	119.97	2.09	119.99	80.00	40.01
140	3.5	69.97	0.71	139.95	2.85	139.98	93.35	46.68
160	4.0	79.96	0.93	159.92	3.72	159.97	106.69	53.36
180	4.5	89.95	1.18	179.89	4.71	179.95	120.03	60.04
200	5.0	99.94	1.45	199.85	5.81	199.93	133.39	66.72
220	5.5	109.93	1.76	219.80	7.03	219.91	146.74	73.39
240	6.0	119.92	2.09	239.74	8.37	239.88	160.09	80.08
260	6.5	129.90	2.45	259.67	9.82	259.85	173.45	86.77
280	7.0	139.89	2.85	279.58	11.39	279.82	186.81	93.46
300	7.5	149.87	3.27	299.49	13.07	299.77	200.18	100.16
320	8.0	159.85	3.72	319.38	14.87	319.73	213.55	106.86
340	8.5	169.83	4.20	339.26	16.79	339.67	226.93	113.57
360	9.0	179.80	4.70	359.12	18.82	359.61	240.31	120.29
380	9.5	189.77	5.24	378.96	20.96	379.54	253.70	127.01
400	10.0	199.74	5.81	398.79	23.22	399.47	267.10	133.73

SPIRAL PARTS FOR 6° CURVE

L	S	q	p	Y	X	C	U	V
60	1.8°	29.99	0.16	59.99	0.63	60.00	40.00	20.00
80	2.4	39.98	0.28	79.99	1.12	79.99	53.33	26.67
100	3.0	49.97	0.44	99.97	1.74	99.99	66.67	33.34
120	3.6	59.96	0.63	119.95	2.51	119.98	80.00	40.01
140	4.2	69.96	0.85	139.93	3.42	139.97	93.35	46.68
160	4.8	79.95	1.12	159.89	4.47	159.95	106.70	53.36
180	5.4	89.93	1.41	179.84	5.65	179.93	120.05	60.05
200	6.0	99.92	1.74	199.78	6.98	199.90	133.41	66.74
220	6.6	109.90	2.11	219.71	8.44	219.87	146.77	73.43
240	7.2	119.88	2.51	239.62	10.04	239.83	160.13	80.12
260	7.8	129.86	2.94	259.52	11.78	259.79	173.50	86.82
280	8.4	139.84	3.41	279.40	13.66	279.74	186.87	93.52
300	9.0	149.81	3.92	299.26	15.68	299.68	200.26	100.24
320	9.6	159.78	4.46	319.11	17.84	319.61	213.65	106.96
340	10.2	169.75	5.03	338.93	20.13	339.53	227.05	113.68
360	10.8	179.71	5.64	358.73	22.56	359.44	240.45	120.41
380	11.4	189.67	6.28	378.51	25.13	379.34	253.87	127.15
400	12.0	199.63	6.96	398.26	27.84	399.23	267.29	133.90

SPIRAL PARTS FOR 7° CURVE

L	S	q	p	Y	X	C	U	V
60	2.1°	29.98	0.18	59.99	0.73	60.00	40.00	20.00
80	2.8	39.97	0.33	79.98	1.30	79.99	53.34	26.67
100	3.5	49.96	0.51	99.96	2.04	99.98	66.68	33.35
120	4.2	59.95	0.73	119.94	2.93	119.97	80.01	40.02
140	4.9	69.94	1.00	139.90	3.99	139.96	93.37	46.70
160	5.6	79.93	1.30	159.85	5.21	159.93	106.72	53.38
180	6.3	89.91	1.65	179.78	6.59	179.90	120.06	60.06
200	7.0	99.89	2.03	199.70	8.14	199.87	133.44	66.75
220	7.7	109.87	2.46	219.61	9.84	219.83	146.81	73.45
240	8.4	119.84	2.92	239.49	11.71	239.77	160.18	80.17
260	9.1	129.81	3.43	259.35	13.74	259.71	173.56	86.88
280	9.8	139.78	3.98	279.19	15.93	279.64	186.95	93.59
300	10.5	149.74	4.57	299.00	18.28	299.56	200.36	100.32
320	11.2	159.70	5.20	318.79	20.79	319.46	213.76	107.05
340	11.9	169.66	5.87	338.54	23.47	339.36	227.18	113.80
360	12.6	179.61	6.57	358.27	26.30	359.24	240.61	120.56
380	13.3	189.55	7.32	377.97	29.29	379.10	254.05	127.33
400	14.0	199.49	8.12	399.63	32.44	398.95	267.51	134.10

372 TABLE XLVIII.—SPIRAL PARTS FOR 8° CURVE

L	S	q	p	Y	X	C	U	V
60	2.4°	29.97	0.21	59.99	0.84	60.00	40.00	20.00
80	3.2	39.96	0.37	79.98	1.49	79.99	53.34	26.67
100	4.0	49.95	0.57	99.95	2.33	99.98	66.68	33.35
120	4.8	59.94	0.84	119.92	3.35	119.96	80.01	40.02
140	5.6	69.92	1.14	139.87	4.56	139.94	93.38	46.71
160	6.4	79.90	1.49	159.80	5.95	159.91	106.74	53.40
180	7.2	89.88	1.88	179.72	7.53	179.88	120.10	60.09
200	8.0	99.86	2.32	199.61	9.30	199.83	133.47	66.79
220	8.8	109.83	2.81	219.48	11.24	219.77	146.85	73.50
240	9.6	119.79	3.34	239.33	13.38	239.70	160.24	80.22
260	10.4	129.76	3.92	259.15	15.69	259.62	173.64	86.94
280	11.2	139.71	4.54	278.94	18.20	279.53	187.04	93.67
300	12.0	149.67	5.22	298.69	20.88	299.42	200.46	100.42
320	12.8	159.61	5.93	318.42	23.75	319.30	213.89	107.17
340	13.6	169.55	6.70	338.10	26.79	339.16	227.34	113.95
360	14.4	179.49	7.51	357.75	30.03	359.00	240.81	120.73
380	15.2	189.42	8.36	377.35	33.44	378.83	254.28	127.53
400	16.0	199.34	9.27	396.91	37.03	398.63	267.77	134.34

SPIRAL PARTS FOR 9° CURVE

L	S	q	p	Y	X	C	U	V
60	2.7°	29.97	0.23	59.99	0.94	59.99	40.01	20.00
80	3.6	39.95	0.42	79.97	1.68	79.99	53.34	26.68
100	4.5	49.94	0.65	99.94	2.62	99.97	66.69	33.35
120	5.4	59.92	0.94	119.89	3.77	119.95	80.02	40.03
140	6.3	69.90	1.28	139.83	5.13	139.93	93.39	46.72
160	7.2	79.88	1.67	159.75	6.69	159.89	106.76	53.41
180	8.1	89.85	2.11	179.64	8.47	179.84	120.13	60.10
200	9.0	99.82	2.61	199.51	10.45	199.78	133.51	66.81
220	9.9	109.78	3.16	219.35	12.64	219.71	146.90	73.53
240	10.8	119.74	3.75	239.15	15.04	239.63	160.30	80.27
260	11.7	129.69	4.40	258.92	17.65	259.52	173.72	87.02
280	12.6	139.64	5.11	278.66	20.46	279.41	187.14	93.77
300	13.5	149.58	5.86	298.35	23.47	299.27	200.59	100.54
320	14.4	159.51	6.67	318.00	26.69	319.11	214.05	107.31
340	15.3	169.44	7.53	337.60	30.11	338.94	227.53	114.11
360	16.2	179.35	8.43	357.15	33.74	358.74	241.02	120.95
380	17.1	189.26	9.39	376.66	37.57	378.52	254.53	127.77
400	18.0	199.16	10.41	396.09	41.60	398.27	268.07	134.61

SPIRAL PARTS FOR 10° CURVE

L	S	q	p	Y	X	C	U	V
60	3.0°	29.96	0.26	59.98	1.05	59.99	40.01	20.01
80	4.0	39.94	0.46	79.96	1.86	79.98	53.35	26.68
100	5.0	49.92	0.72	99.92	2.91	99.97	66.69	33.36
120	6.0	59.90	1.04	119.87	4.19	119.94	80.03	40.04
140	7.0	69.88	1.42	139.79	5.70	139.91	93.41	46.73
160	8.0	79.85	1.85	159.69	7.44	159.86	106.78	53.42
180	9.0	89.81	2.35	179.56	9.41	179.81	120.15	60.13
200	10.0	99.78	2.90	199.40	11.61	199.73	133.55	66.86
220	11.0	109.73	3.50	219.20	14.04	219.64	146.95	73.59
240	12.0	119.68	4.17	238.96	16.70	239.54	160.37	80.34
260	13.0	129.62	4.89	258.67	19.59	259.41	173.81	87.10
280	14.0	139.56	5.67	278.34	22.71	279.27	187.25	93.87
300	15.0	149.48	6.51	297.96	26.05	299.10	200.73	100.66
320	16.0	159.40	7.40	317.53	29.62	318.91	214.22	107.46
340	17.0	169.31	8.35	337.04	33.42	338.69	227.73	114.30
360	18.0	179.20	9.36	356.49	37.44	358.44	241.26	121.16
380	19.0	189.09	10.42	375.87	41.68	378.17	254.82	128.02
400	20.0	198.97	11.55	395.18	46.14	397.87	268.40	134.92

TABLE XLVIII.—SPIRAL PARTS FOR 12° CURVE 373

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	3.6°	29.94	0.31	59.98	1.26	59.99	40.01	20.01
80	4.8	39.92	0.56	79.94	2.23	79.98	53.35	26.68
100	6.0	49.89	0.87	99.89	3.49	99.95	66.70	33.37
120	7.2	59.86	1.25	119.81	5.02	119.92	80.06	40.06
140	8.4	69.82	1.70	139.70	6.83	139.87	93.44	46.76
160	9.6	79.78	2.22	159.55	8.92	159.80	106.83	53.48
180	10.8	89.73	2.81	179.37	11.28	179.72	120.23	60.21
200	12.0	99.68	3.47	199.13	13.92	199.62	133.64	66.95
220	13.2	109.61	4.19	218.84	16.83	219.49	147.08	73.71
240	14.4	119.54	4.99	238.50	20.02	239.34	160.54	80.49
260	15.6	129.46	5.85	259.09	23.47	259.16	174.02	87.29
280	16.8	139.36	6.79	277.62	27.20	278.94	187.53	94.12
300	18.0	149.25	7.79	297.07	31.20	298.70	201.05	100.96
320	19.2	159.14	8.86	316.45	35.46	318.43	214.61	107.83
340	20.4	169.00	9.99	335.74	39.99	338.11	228.21	114.73
360	21.6	178.86	11.20	354.95	44.79	357.76	241.82	121.67
380	22.8	188.68	12.47	374.06	49.86	377.37	255.48	128.63
400	24.0	198.52	13.81	393.08	55.16	396.93	269.18	135.62

SPIRAL PARTS FOR 14° CURVE

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	4.2°	29.92	0.36	59.97	1.47	59.99	40.01	20.01
80	5.6	39.89	0.65	79.92	2.60	79.97	53.36	26.69
100	7.0	49.85	1.01	99.85	4.07	99.93	66.72	33.38
120	8.4	59.81	1.45	119.74	5.86	119.89	80.09	40.08
140	9.8	69.76	1.98	139.59	7.97	139.82	93.48	46.80
160	11.2	79.70	2.58	159.39	10.40	159.73	106.89	53.53
180	12.6	89.64	3.27	179.14	13.15	179.62	120.31	60.28
200	14.0	99.56	4.03	198.82	16.22	199.48	133.76	67.05
220	15.4	109.47	4.88	218.42	19.61	219.30	147.23	73.85
240	16.8	119.37	5.80	237.96	23.32	239.10	160.73	80.67
260	18.2	129.26	6.81	257.40	27.33	258.85	174.26	87.52
280	19.6	139.13	7.89	276.76	31.67	278.56	187.83	94.40
300	21.0	148.99	9.06	296.02	36.31	298.24	201.44	101.31
320	22.4	158.83	10.30	315.17	41.25	317.86	214.08	108.28
340	23.8	168.65	11.62	334.21	46.51	337.43	228.76	115.25
360	25.2	178.45	13.02	353.13	52.06	356.95	242.50	122.28
380	26.6	188.23	14.49	371.93	57.92	376.42	256.27	129.35
400	28.0	197.99	16.05	390.60	64.07	395.82	270.10	136.47

SPIRAL PARTS FOR 15° CURVE

<i>L</i>	<i>S</i>	<i>q</i>	<i>p</i>	<i>Y</i>	<i>X</i>	<i>C</i>	<i>U</i>	<i>V</i>
60	4.5°	29.91	0.39	59.96	1.57	59.98	40.01	20.01
80	6.0	39.87	0.69	79.91	2.79	79.96	53.36	26.69
100	7.5	49.83	1.08	99.83	4.36	99.92	66.73	33.39
120	9.0	59.78	1.56	119.71	6.27	119.87	80.11	40.10
140	10.5	69.73	2.12	139.53	8.53	139.79	93.50	46.82
160	12.0	79.66	2.76	159.30	11.14	159.69	106.91	53.56
180	13.5	89.58	3.50	179.01	14.08	179.56	120.35	60.32
200	15.0	99.50	4.32	198.64	17.37	199.40	133.82	67.11
220	16.5	109.40	5.22	218.19	21.00	219.20	147.31	73.92
240	18.0	119.28	6.21	237.66	24.96	238.96	160.84	80.77
260	19.5	129.15	7.28	257.02	29.26	258.68	174.40	87.64
280	21.0	139.00	8.44	276.28	33.89	278.35	188.01	93.56
300	22.5	148.84	9.69	295.43	38.84	297.97	201.65	101.51
320	24.0	158.65	11.01	314.46	44.13	317.54	215.34	108.50
340	25.5	168.45	12.42	333.36	49.74	337.05	229.08	115.54
360	27.0	178.22	13.92	352.13	55.67	356.50	242.87	122.62
380	28.5	187.97	15.49	370.75	61.92	375.89	256.72	129.76
400	30.0	197.69	17.15	389.23	68.48	395.21	270.63	136.95

374 TABLE XLVIII.—SPIRAL PARTS FOR 16° CURVE

L	S	q	p	Y	X	C	U	V
60	4.8°	29.90	0.41	59.96	1.67	59.98	40.01	20.01
80	6.4	39.85	0.74	79.90	2.98	79.96	53.37	26.70
100	8.0	49.81	1.15	99.81	4.65	99.91	66.74	33.40
120	9.6	59.75	1.66	119.67	6.69	119.85	80.12	40.12
140	11.2	69.69	2.26	139.47	9.10	139.77	93.52	46.84
160	12.8	79.61	2.95	159.21	11.87	159.65	106.95	53.59
180	14.4	89.53	3.73	178.87	15.01	179.50	120.40	60.37
200	16.0	99.43	4.60	198.45	18.51	199.32	133.89	67.17
220	17.6	109.31	5.56	217.94	22.38	219.09	147.40	74.01
240	19.2	119.18	6.61	237.33	26.60	238.82	160.95	80.87
260	20.8	129.04	7.76	256.61	31.17	258.50	174.55	87.78
280	22.4	138.87	8.99	275.77	36.10	278.13	188.19	94.73
300	24.0	148.68	10.31	294.81	41.37	297.70	201.88	101.72
320	25.6	158.47	11.72	313.70	46.99	317.20	215.62	108.76
340	27.2	168.24	13.23	332.46	52.95	336.65	229.42	115.85
360	28.8	177.98	14.81	351.06	59.25	356.02	243.28	122.99
380	30.4	187.70	16.49	369.50	65.89	375.49	257.21	130.20
400	32.0	197.38	17.70	387.77	72.85	394.55	271.19	137.47

SPIRAL PARTS FOR 18° CURVE

L	S	q	p	Y	X	C	U	V
60	5.4°	29.87	0.47	59.95	1.88	59.98	40.02	20.02
80	7.2	39.82	0.83	79.87	3.35	79.94	53.38	26.71
100	9.0	49.75	1.29	99.75	5.23	99.89	66.75	33.41
120	10.8	59.68	1.86	119.58	7.52	119.81	80.15	40.14
140	12.6	69.60	2.53	139.33	10.23	139.70	93.57	46.88
160	14.4	79.51	3.30	159.00	13.34	159.56	107.02	53.66
180	16.2	89.40	4.18	178.57	16.87	179.37	120.51	60.47
200	18.0	99.28	5.16	198.05	20.80	199.14	134.03	67.31
220	19.8	109.13	6.23	217.40	25.13	218.85	147.60	74.19
240	21.6	118.97	7.41	236.63	29.86	238.51	161.22	81.11
260	23.4	128.78	8.69	255.72	34.98	258.10	174.88	88.08
280	25.2	138.57	10.07	274.66	40.49	277.63	188.61	95.11
300	27.0	148.34	11.55	293.44	46.39	297.09	202.39	102.19
320	28.8	158.07	13.13	312.05	52.67	316.47	216.25	109.33
340	30.6	167.78	14.81	330.48	59.32	335.76	230.17	116.54
360	32.4	177.45	16.59	348.72	66.34	354.97	244.18	123.82
380	34.2	187.09	18.46	366.75	73.73	374.09	258.26	131.17
400	36.0	196.70	20.43	384.58	81.47	393.11	272.44	138.61

SPIRAL PARTS FOR 20° CURVE

L	S	q	p	Y	X	C	U	V
60	6.0°	29.84	0.52	59.93	2.09	59.97	40.02	20.02
80	8.0	39.77	0.92	79.85	3.72	79.93	53.39	26.72
100	10.0	49.70	1.43	99.70	5.81	99.87	66.77	33.43
120	12.0	59.61	2.06	119.48	8.35	119.77	80.19	40.18
140	14.0	69.51	2.80	139.17	11.35	139.63	93.63	46.93
160	16.0	79.40	3.66	158.76	14.81	159.45	107.11	53.74
180	18.0	89.26	4.63	178.24	18.72	179.22	120.63	60.58
200	20.0	99.11	5.71	197.59	23.07	198.93	134.20	67.46
220	22.0	108.93	6.90	216.80	27.87	218.58	147.82	74.39
240	24.0	118.73	8.20	235.85	33.10	238.16	161.51	81.37
260	26.0	128.50	9.62	254.73	38.76	257.66	175.25	88.42
280	28.0	138.24	11.15	273.42	44.85	277.08	189.07	95.53
300	30.0	147.95	12.78	291.92	51.36	296.41	202.97	102.71
320	32.0	157.63	14.52	310.21	58.28	315.64	216.95	109.97
340	34.0	167.27	16.38	328.28	65.60	334.77	231.02	117.32
360	36.0	176.87	18.34	346.12	73.33	353.80	245.19	124.75
380	38.0	186.43	20.40	363.71	81.44	372.71	259.47	132.28
400	40.0	195.95	22.57	381.04	89.94	391.51	273.86	139.92

SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
0.0°	1.00000	1.00000	.00000	.66667	.33333	.00000	.0000	.50000	.0000	0.0°
.1	1.00000	1.00000	.00058	.66667	.33333	.00015	.0000	.50000	.0001	.1
.2	1.00000	1.00000	.00116	.66667	.33333	.00029	.0000	.50000	.0002	.2
.3	1.00000	1.00000	.00175	.66667	.33333	.00044	.0000	.50000	.0004	.3
.4	1.00000	1.00000	.00233	.66667	.33333	.00058	.0000	.50000	.0005	.4
.5	1.00000	.99999	.00291	.66667	.33334	.00073	.0000	.50000	.0006	.5
.6	1.00000	.99999	.00349	.66667	.33334	.00087	.0000	.50000	.0008	.6
.7	.99999	.99999	.00407	.66667	.33334	.00102	.0000	.50000	.0009	.7
.8	.99999	.99998	.00465	.66667	.33334	.00116	.0000	.50000	.0010	.8
.9	.99999	.99998	.00524	.66668	.33334	.00131	.0000	.50000	.0011	.9
1.0	.99999	.99997	.00582	.66668	.33334	.00145	.0000	.49999	.0013	1.0
.1	.99998	.99996	.00640	.66668	.33335	.00160	.0000	.49999	.0014	.1
.2	.99998	.99996	.00698	.66668	.33335	.00175	.0000	.49999	.0015	.2
.3	.99998	.99995	.00756	.66668	.33335	.00189	.0000	.49999	.0017	.3
.4	.99997	.99994	.00814	.66669	.33335	.00204	.0000	.49999	.0018	.4
.5	.99997	.99993	.00873	.66669	.33336	.00218	.0000	.49999	.0019	.5
.6	.99997	.99992	.00931	.66669	.33336	.00233	.0000	.49999	.0020	.6
.7	.99996	.99991	.00989	.66670	.33336	.00247	.0000	.49999	.0022	.7
.8	.99996	.99990	.01047	.66670	.33337	.00262	.0000	.49998	.0023	.8
.9	.99995	.99989	.01105	.66671	.33337	.00276	.0000	.49998	.0024	.9
2.0	.99995	.99988	.01163	.66671	.33337	.00291	.0000	.49998	.0025	2.0
.1	.99994	.99987	.01222	.66671	.33338	.00305	.0000	.49998	.0027	.1
.2	.99994	.99985	.01280	.66672	.33338	.00320	.0000	.49998	.0028	.2
.3	.99993	.99984	.01338	.66672	.33338	.00335	.0001	.49997	.0029	.3
.4	.99992	.99983	.01396	.66673	.33339	.00349	.0001	.49997	.0031	.4
.5	.99992	.99981	.01454	.66673	.33339	.00364	.0001	.49997	.0032	.5
.6	.99991	.99980	.01512	.66674	.33340	.00378	.0001	.49997	.0033	.6
.7	.99990	.99978	.01571	.66674	.33340	.00393	.0001	.49996	.0034	.7
.8	.99990	.99977	.01629	.66675	.33341	.00407	.0001	.49996	.0036	.8
.9	.99989	.99975	.01687	.66676	.33342	.00422	.0001	.49996	.0037	.9
3.0	.99988	.99973	.01745	.66676	.33342	.00436	.0001	.49996	.0038	3.0
.1	.99987	.99971	.01803	.66677	.33343	.00451	.0001	.49995	.0039	.1
.2	.99986	.99969	.01861	.66678	.33343	.00465	.0001	.49995	.0041	.2
.3	.99985	.99967	.01919	.66678	.33344	.00480	.0001	.49995	.0042	.3
.4	.99985	.99965	.01978	.66679	.33345	.00494	.0001	.49994	.0043	.4
.5	.99984	.99963	.02036	.66680	.33345	.00509	.0001	.49994	.0045	.5
.6	.99983	.99961	.02094	.66681	.33346	.00524	.0001	.49994	.0046	.6
.7	.99982	.99959	.02152	.66681	.33347	.00538	.0001	.49993	.0047	.7
.8	.99981	.99956	.02210	.66682	.33347	.00553	.0002	.49993	.0048	.8
.9	.99980	.99954	.02268	.66683	.33348	.00567	.0002	.49993	.0050	.9
4.0	.99979	.99952	.02326	.66684	.33349	.00582	.0002	.49992	.0051	4.0
.1	.99978	.99949	.02384	.66685	.33350	.00596	.0002	.49992	.0052	.1
.2	.99976	.99947	.02443	.66686	.33351	.00611	.0002	.49991	.0053	.2
.3	.99975	.99944	.02501	.66686	.33351	.00625	.0002	.49991	.0055	.3
.4	.99974	.99941	.02559	.66687	.33352	.00640	.0002	.49991	.0056	.4
.5	.99973	.99939	.02617	.66688	.33353	.00654	.0002	.49990	.0057	.5
.6	.99972	.99936	.02675	.66689	.33354	.00669	.0002	.49990	.0059	.6
.7	.99970	.99933	.02733	.66690	.33355	.00683	.0002	.49989	.0060	.7
.8	.99969	.99930	.02791	.66691	.33356	.00698	.0003	.49989	.0061	.8
.9	.99968	.99927	.02849	.66692	.33357	.00713	.0003	.49988	.0062	.9
5.0	.99967	.99924	.02907	.66693	.33358	.00727	.0003	.49988	.0064	5.0
.1	.99965	.99921	.02965	.66695	.33359	.00742	.0003	.49987	.0065	.1
.2	.99964	.99918	.03023	.66696	.33360	.00756	.0003	.49987	.0066	.2
.3	.99962	.99915	.03082	.66697	.33361	.00771	.0003	.49986	.0067	.3
.4	.99961	.99912	.03140	.66698	.33362	.00785	.0003	.49986	.0069	.4
.5	.99960	.99908	.03198	.66699	.33363	.00800	.0003	.49985	.0070	.5
.6	.99958	.99905	.03256	.66700	.33364	.00814	.0003	.49985	.0071	.6
.7	.99957	.99902	.03314	.66702	.33365	.00829	.0004	.49984	.0073	.7
.8	.99955	.99898	.03372	.66703	.33366	.00843	.0004	.49984	.0074	.8
.9	.99953	.99895	.03430	.66704	.33367	.00858	.0004	.49983	.0075	.9

376 TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD
SPIRAL

<i>S</i>	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		<i>S</i>
						<i>a</i>	<i>b</i>	<i>e</i>	<i>f</i>	
6.0°	.99952	.99891	.03488	.66705	.33369	.00872	.0004	.49982	.0076	6.0°
.1	.99950	.99887	.03546	.66707	.33370	.00887	.0004	.49982	.0078	.1
.2	.99949	.99884	.03604	.66708	.33371	.00901	.0004	.49981	.0079	.2
.3	.99947	.99880	.03662	.66709	.33372	.00916	.0004	.49981	.0080	.3
.4	.99945	.99876	.03720	.66711	.33373	.00930	.0005	.49980	.0081	.4
.5	.99944	.99872	.03778	.66712	.33375	.00945	.0005	.49979	.0083	.5
.6	.99942	.99868	.03836	.66713	.33376	.00959	.0005	.49979	.0084	.6
.7	.99940	.99864	.03894	.66715	.33377	.00974	.0005	.49978	.0085	.7
.8	.99938	.99860	.03952	.66716	.33379	.00989	.0005	.49977	.0086	.8
.9	.99936	.99856	.04010	.66718	.33380	.01003	.0005	.49977	.0088	.9
7.0	.99935	.99852	.04068	.66719	.33381	.01018	.0005	.49976	.0089	7.0
.1	.99933	.99847	.04126	.66721	.33383	.01032	.0006	.49975	.0090	.1
.2	.99931	.99843	.04184	.66722	.33384	.01047	.0006	.49975	.0091	.2
.3	.99929	.99839	.04242	.66724	.33385	.01061	.0006	.49974	.0093	.3
.4	.99927	.99834	.04300	.66725	.33387	.01076	.0006	.49973	.0094	.4
.5	.99925	.99830	.04358	.66727	.33388	.01090	.0006	.49972	.0095	.5
.6	.99923	.99825	.04416	.66729	.33390	.01105	.0006	.49972	.0097	.6
.7	.99921	.99821	.04474	.66730	.33391	.01119	.0007	.49971	.0098	.7
.8	.99919	.99816	.04532	.66732	.33393	.01134	.0007	.49970	.0099	.8
.9	.99917	.99811	.04590	.66734	.33394	.01148	.0007	.49969	.0100	.9
8.0	.99914	.99806	.04648	.66735	.33396	.01163	.0007	.49969	.0102	8.0
.1	.99912	.99801	.04706	.66737	.33398	.01177	.0007	.49968	.0103	.1
.2	.99910	.99797	.04764	.66739	.33399	.01192	.0007	.49967	.0104	.2
.3	.99908	.99792	.04822	.66741	.33401	.01206	.0008	.49966	.0105	.3
.4	.99906	.99788	.04880	.66742	.33402	.01221	.0008	.49965	.0107	.4
.5	.99903	.99781	.04937	.66744	.33404	.01235	.0008	.49965	.0108	.5
.6	.99901	.99776	.04995	.66746	.33406	.01250	.0008	.49964	.0109	.6
.7	.99899	.99771	.05053	.66748	.33407	.01264	.0008	.49963	.0110	.7
.8	.99897	.99766	.05111	.66750	.33409	.01279	.0009	.49962	.0112	.8
.9	.99894	.99760	.05169	.66752	.33411	.01293	.0009	.49961	.0113	.9
9.0	.99892	.99755	.05227	.66754	.33413	.01308	.0009	.49960	.0114	9.0
.1	.99889	.99749	.05285	.66756	.33414	.01322	.0009	.49959	.0116	.1
.2	.99887	.99744	.05342	.66758	.33416	.01337	.0009	.49959	.0117	.2
.3	.99884	.99738	.05400	.66760	.33418	.01351	.0010	.49958	.0118	.3
.4	.99882	.99733	.05458	.66762	.33420	.01366	.0010	.49957	.0119	.4
.5	.99879	.99727	.05516	.66764	.33422	.01381	.0010	.49956	.0120	.5
.6	.99877	.99721	.05574	.66766	.33424	.01395	.0010	.49955	.0122	.6
.7	.99874	.99715	.05632	.66768	.33425	.01410	.0010	.49954	.0123	.7
.8	.99872	.99709	.05690	.66770	.33427	.01424	.0011	.49953	.0124	.8
.9	.99869	.99704	.05747	.66772	.33429	.01439	.0011	.49952	.0126	.9
10.0	.99866	.99698	.05805	.66774	.33431	.01453	.0011	.49951	.0127	10.0
.1	.99864	.99691	.05863	.66776	.33433	.01468	.0011	.49950	.0128	.1
.2	.99861	.99685	.05921	.66779	.33435	.01482	.0012	.49949	.0129	.2
.3	.99858	.99679	.05979	.66781	.33437	.01497	.0012	.49948	.0131	.3
.4	.99856	.99673	.06036	.66783	.33439	.01511	.0012	.49947	.0132	.4
.5	.99853	.99667	.06094	.66785	.33441	.01526	.0012	.49946	.0133	.5
.6	.99850	.99660	.06152	.66787	.33443	.01540	.0012	.49945	.0134	.6
.7	.99847	.99654	.06210	.66790	.33446	.01555	.0013	.49944	.0136	.7
.8	.99844	.99647	.06267	.66792	.33448	.01569	.0013	.49943	.0137	.8
.9	.99841	.99641	.06325	.66794	.33450	.01584	.0013	.49942	.0138	.9
11.0	.99838	.99634	.06383	.66797	.33452	.01598	.0013	.49941	.0139	11.0
.1	.99835	.99627	.06441	.66799	.33454	.01612	.0014	.49940	.0141	.1
.2	.99832	.99621	.06498	.66802	.33456	.01627	.0014	.49939	.0142	.2
.3	.99829	.99614	.06556	.66804	.33459	.01641	.0014	.49937	.0143	.3
.4	.99826	.99607	.06614	.66806	.33461	.01656	.0014	.49936	.0144	.4
.5	.99823	.99600	.06671	.66809	.33463	.01670	.0015	.49935	.0146	.5
.6	.99820	.99593	.06729	.66811	.33465	.01685	.0015	.49934	.0147	.6
.7	.99817	.99586	.06787	.66814	.33468	.01699	.0015	.49933	.0148	.7
.8	.99814	.99579	.06844	.66816	.33470	.01714	.0015	.49932	.0149	.8
.9	.99811	.99572	.06902	.66819	.33472	.01728	.0016	.49931	.0151	.9

SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
12.0°	.99308	.99565	.06960	.66822	.33475	.01743	.0016	.49929	.0152	12.0°
.1	.99304	.99567	.07017	.66824	.33477	.01757	.0016	.49928	.0153	.1
.2	.99801	.99550	.07075	.66827	.33479	.01772	.0016	.49927	.0154	.2
.3	.99798	.99543	.07133	.66830	.33482	.01786	.0017	.49926	.0156	.3
.4	.99795	.99535	.07190	.66832	.33484	.01801	.0017	.49925	.0157	.4
.5	.99791	.99528	.07248	.66835	.33487	.01815	.0017	.49923	.0158	.5
.6	.99788	.99520	.07305	.66838	.33489	.01830	.0018	.49922	.0159	.6
.7	.99785	.99513	.07363	.66840	.33492	.01844	.0018	.49921	.0160	.7
.8	.99781	.99505	.07421	.66843	.33494	.01859	.0018	.49920	.0162	.8
.9	.99778	.99497	.07478	.66846	.33497	.01873	.0018	.49918	.0163	.9
13.0	.99774	.99489	.07536	.66849	.33499	.01888	.0019	.49917	.0164	13.0
.1	.99771	.99481	.07593	.66852	.33502	.01902	.0019	.49916	.0165	.1
.2	.99767	.99474	.07651	.66854	.33504	.01917	.0019	.49915	.0167	.2
.3	.99764	.99466	.07708	.66857	.33507	.01931	.0020	.49913	.0168	.3
.4	.99760	.99457	.07766	.66860	.33510	.01946	.0020	.49912	.0169	.4
.5	.99757	.99449	.07823	.66863	.33512	.01960	.0020	.49911	.0170	.5
.6	.99753	.99441	.07881	.66866	.33515	.01974	.0020	.49909	.0172	.6
.7	.99749	.99433	.07938	.66869	.33518	.01989	.0021	.49908	.0173	.7
.8	.99746	.99425	.07996	.66872	.33520	.02003	.0021	.49907	.0174	.8
.9	.99742	.99416	.08053	.66875	.33523	.02018	.0021	.49905	.0175	.9
14.0	.99738	.99408	.08111	.66878	.33526	.02032	.0022	.49905	.0177	14.0
.1	.99735	.99399	.08168	.66881	.33529	.02047	.0022	.49903	.0178	.1
.2	.99731	.99391	.08226	.66884	.33531	.02061	.0022	.49901	.0179	.2
.3	.99727	.99382	.08283	.66887	.33534	.02076	.0023	.49900	.0180	.3
.4	.99723	.99374	.08340	.66890	.33537	.02090	.0023	.49898	.0182	.4
.5	.99719	.99365	.08398	.66893	.33540	.02105	.0023	.49897	.0183	.5
.6	.99715	.99356	.08455	.66897	.33543	.02119	.0024	.49896	.0184	.6
.7	.99711	.99347	.08513	.66900	.33546	.02134	.0024	.49894	.0185	.7
.8	.99708	.99339	.08570	.66903	.33549	.02148	.0024	.49893	.0186	.8
.9	.99704	.99330	.08627	.66906	.33552	.02162	.0025	.49891	.0188	.9
15.0	.99700	.99321	.08685	.66909	.33555	.02177	.0025	.49890	.0189	15.0
.1	.99696	.99312	.08742	.66913	.33558	.02191	.0025	.49888	.0190	.1
.2	.99692	.99302	.08799	.66916	.33561	.02206	.0026	.49887	.0191	.2
.3	.99687	.99293	.08857	.66919	.33464	.02220	.0026	.49885	.0193	.3
.4	.99683	.99284	.08914	.66923	.33567	.02235	.0026	.49884	.0194	.4
.5	.99679	.99275	.08971	.66926	.33570	.02249	.0026	.49882	.0195	.5
.6	.99675	.99265	.09028	.66929	.33573	.02264	.0027	.49881	.0196	.6
.7	.99671	.99256	.09086	.66933	.33576	.02278	.0027	.49879	.0198	.7
.8	.99667	.99246	.09143	.66936	.33579	.02292	.0028	.49878	.0199	.8
.9	.99662	.99237	.09200	.66940	.33582	.02307	.0028	.49876	.0200	.9
16.0	.99658	.99227	.09257	.66943	.33585	.02321	.0028	.49875	.0201	16.0
.1	.99654	.99218	.09315	.66947	.33588	.02336	.0029	.49873	.0202	.3
.2	.99650	.99208	.09372	.66950	.33592	.02350	.0029	.49872	.0204	.2
.3	.99645	.99198	.09429	.66954	.33595	.02365	.0029	.49870	.0205	.3
.4	.99641	.99188	.09486	.66957	.33598	.02379	.0030	.49868	.0206	.4
.5	.99637	.99178	.09543	.66961	.33601	.02393	.0030	.49867	.0207	.5
.6	.99632	.99169	.09600	.66964	.33605	.02408	.0030	.49865	.0209	.6
.7	.99628	.99159	.09658	.66968	.33608	.02422	.0031	.49863	.0210	.7
.8	.99623	.99148	.09715	.66972	.33611	.02437	.0031	.49862	.0211	.8
.9	.99619	.99138	.09772	.66975	.33615	.02451	.0032	.49860	.0212	.9
17.0	.99614	.99128	.09829	.66979	.33618	.02466	.0032	.49859	.0213	17.0
.1	.99610	.99118	.09886	.66983	.33621	.02480	.0032	.49857	.0215	.1
.2	.99605	.99108	.09943	.66986	.33625	.02494	.0033	.49855	.0216	.2
.3	.99600	.99097	.10000	.66990	.33628	.02509	.0033	.49853	.0217	.3
.4	.99596	.99087	.10057	.66994	.33632	.02523	.0033	.49852	.0218	.4
.5	.99591	.99076	.10114	.66998	.33635	.02538	.0034	.49850	.0220	.5
.6	.99587	.99066	.10171	.67002	.33639	.02552	.0034	.49848	.0221	.6
.7	.99582	.99055	.10228	.67005	.33642	.02567	.0035	.49847	.0222	.7
.8	.99577	.99044	.10285	.67009	.33646	.02581	.0035	.49845	.0223	.8
.9	.99572	.99034	.10342	.67013	.33649	.02595	.0035	.49843	.0224	.9

378 TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
18.0°	.99568	.99023	.10399	.67017	.33653	.02610	.0036	.49841	.0226	18.0°
.1	.99563	.99012	.10456	.67021	.33657	.02624	.0036	.49840	.0227	.1
.2	.99558	.99001	.10513	.67025	.33660	.02639	.0037	.49838	.0228	.2
.3	.99553	.98990	.10570	.67029	.33664	.02653	.0037	.49836	.0229	.3
.4	.99548	.98979	.10627	.67033	.33667	.02667	.0037	.49834	.0230	.4
.5	.99543	.98968	.10684	.67037	.33671	.02682	.0038	.49833	.0232	.5
.6	.99538	.98957	.10741	.67041	.33675	.02696	.0038	.49831	.0233	.6
.7	.99533	.98946	.10798	.67045	.33679	.02711	.0039	.49829	.0234	.7
.8	.99528	.98935	.10855	.67049	.33682	.02725	.0039	.49827	.0235	.8
.9	.99523	.98923	.10912	.67053	.33686	.02739	.0039	.49825	.0236	.9
19.0	.99518	.98912	.10968	.67058	.33690	.02754	.0040	.49823	.0238	19.0
.1	.99513	.98901	.11025	.67062	.33694	.02768	.0040	.49821	.0239	.1
.2	.99508	.98889	.11082	.67066	.33697	.02783	.0041	.49820	.0240	.2
.3	.99503	.98878	.11139	.67070	.33701	.02797	.0041	.49818	.0241	.3
.4	.99498	.98866	.11196	.67074	.33705	.02811	.0041	.49816	.0242	.4
.5	.99493	.98854	.11252	.67079	.33709	.02826	.0042	.49814	.0244	.5
.6	.99487	.98843	.11309	.67083	.33713	.02840	.0042	.49812	.0245	.6
.7	.99482	.98831	.11366	.67087	.33717	.02854	.0043	.49810	.0246	.7
.8	.99477	.98819	.11423	.67092	.33721	.02869	.0043	.49808	.0247	.8
.9	.99472	.98807	.11479	.67096	.33725	.02883	.0044	.49806	.0248	.9
20.0	.99466	.98795	.11536	.67100	.33729	.02898	.0044	.49804	.0250	20.0
.1	.99461	.98783	.11593	.67105	.33733	.02912	.0044	.49802	.0251	.1
.2	.99456	.98771	.11649	.67109	.33737	.02926	.0045	.49800	.0252	.2
.3	.99450	.98759	.11706	.67114	.33741	.02941	.0045	.49798	.0253	.3
.4	.99445	.98747	.11763	.67118	.33745	.02955	.0046	.49796	.0254	.4
.5	.99439	.98734	.11819	.67123	.33749	.02969	.0046	.49794	.0256	.5
.6	.99434	.98722	.11876	.67127	.33753	.02984	.0047	.49792	.0257	.6
.7	.99428	.98710	.11932	.67132	.33757	.02998	.0047	.49790	.0258	.7
.8	.99423	.98697	.11989	.67136	.33762	.03013	.0048	.49788	.0259	.8
.9	.99417	.98685	.12046	.67141	.33766	.03027	.0048	.49786	.0260	.9
21.0	.99412	.98672	.12102	.67145	.33770	.03041	.0048	.49784	.0262	21.0
.1	.99406	.98660	.12159	.67150	.33774	.03056	.0049	.49782	.0263	.1
.2	.99400	.98647	.12215	.67155	.33778	.03070	.0049	.49780	.0264	.2
.3	.99395	.98634	.12272	.67159	.33783	.03084	.0050	.49778	.0265	.3
.4	.99389	.98622	.12328	.67164	.33787	.03099	.0050	.49776	.0266	.4
.5	.99383	.98609	.12385	.67169	.33791	.03113	.0051	.49774	.0267	.5
.6	.99378	.98596	.12441	.67173	.33796	.03127	.0051	.49772	.0268	.6
.7	.99372	.98583	.12497	.67178	.33800	.03142	.0052	.49770	.0270	.7
.8	.99366	.98570	.12554	.67183	.33804	.03156	.0052	.49768	.0271	.8
.9	.99360	.98557	.12610	.67188	.33809	.03170	.0053	.49766	.0272	.9
22.0	.99354	.98544	.12667	.67193	.33813	.03185	.0053	.49763	.0273	22.0
.1	.99349	.98531	.12723	.67197	.33818	.03199	.0054	.49761	.0275	.1
.2	.99343	.98517	.12779	.67202	.33822	.03213	.0054	.49759	.0276	.2
.3	.99337	.98504	.12836	.67207	.33827	.03228	.0055	.49757	.0277	.3
.4	.99331	.98491	.12892	.67212	.33831	.03242	.0055	.49755	.0278	.4
.5	.99325	.98477	.12948	.67217	.33836	.03256	.0056	.49752	.0279	.5
.6	.99319	.98464	.13005	.67222	.33840	.03271	.0056	.49750	.0281	.6
.7	.99313	.98450	.13061	.67227	.33845	.03285	.0057	.49748	.0282	.7
.8	.99307	.98437	.13117	.67232	.33849	.03299	.0057	.49746	.0283	.8
.9	.99301	.98423	.13173	.67237	.33854	.03314	.0058	.49744	.0284	.9
23.0	.99295	.98409	.13230	.67242	.33859	.03328	.0058	.49741	.0285	23.0
.1	.99288	.98396	.13286	.67247	.33863	.03342	.0059	.49739	.0286	.1
.2	.99282	.98382	.13342	.67252	.33868	.03357	.0059	.49737	.0288	.2
.3	.99276	.98368	.13398	.67258	.33873	.03371	.0060	.49735	.0289	.3
.4	.99270	.98354	.13454	.67263	.33877	.03385	.0060	.49732	.0290	.4
.5	.99264	.98340	.13510	.67268	.33882	.03400	.0061	.49730	.0291	.5
.6	.99257	.98326	.13567	.67273	.33887	.03414	.0061	.49728	.0292	.6
.7	.99251	.98312	.13623	.67278	.33892	.03428	.0062	.49725	.0293	.7
.8	.99245	.98298	.13679	.67284	.33896	.03443	.0062	.49723	.0295	.8
.9	.99238	.98283	.13735	.67289	.33901	.03457	.0063	.49721	.0296	.9

TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD 379

SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-\lambda D$		$q=eL-fD$		S
						a	b	e	f	
24.0°	.99232	.98269	.13791	.67294	.33906	.03471	.0063	.49718	.0297	24.0°
.1	.99226	.98255	.13847	.67300	.33911	.03485	.0064	.49716	.0298	.1
.2	.99219	.98240	.13903	.67305	.33916	.03500	.0064	.49714	.0299	.2
.3	.99213	.98226	.13959	.67310	.33921	.03514	.0065	.49711	.0300	.3
.4	.99206	.98211	.14015	.67316	.33926	.03528	.0065	.49709	.0302	.4
.5	.99200	.98197	.14071	.67321	.33931	.03543	.0066	.49707	.0303	.5
.6	.99193	.98182	.14127	.67327	.33936	.03557	.0066	.49704	.0304	.6
.7	.99187	.98167	.14183	.67332	.33941	.03571	.0067	.49702	.0305	.7
.8	.99180	.98153	.14239	.67338	.33946	.03585	.0067	.49699	.0306	.8
.9	.99174	.98138	.14295	.67343	.33951	.03600	.0068	.49697	.0307	.9
25.0	.99167	.98123	.14350	.67349	.33956	.03614	.0068	.49695	.0309	25.0
.1	.99160	.98108	.14406	.67354	.33961	.03628	.0069	.49692	.0310	.1
.2	.99154	.98093	.14462	.67360	.33966	.03643	.0069	.49690	.0311	.2
.3	.99147	.98078	.14518	.67365	.33971	.03657	.0070	.49687	.0312	.3
.4	.99140	.98063	.14574	.67371	.33976	.03671	.0071	.49685	.0313	.4
.5	.99133	.98048	.14629	.67377	.33981	.03685	.0071	.49682	.0314	.5
.6	.99127	.98033	.14685	.67382	.33987	.03700	.0072	.49680	.0315	.6
.7	.99120	.98017	.14741	.67388	.33992	.03714	.0072	.49677	.0317	.7
.8	.99113	.98002	.14797	.67394	.33997	.03728	.0073	.49675	.0318	.8
.9	.99106	.97987	.14852	.67400	.34002	.03742	.0073	.49672	.0319	.9
26.0	.99099	.97971	.14908	.67405	.34008	.03757	.0074	.49670	.0320	26.0
.1	.99092	.97956	.14964	.67411	.34013	.03771	.0074	.49667	.0321	.1
.2	.99085	.97940	.15019	.67417	.34018	.03785	.0075	.49665	.0322	.2
.3	.99078	.97925	.15075	.67423	.34024	.03800	.0076	.49662	.0323	.3
.4	.99071	.97909	.15131	.67429	.34029	.03814	.0076	.49660	.0325	.4
.5	.99064	.97893	.15186	.67435	.34035	.03828	.0077	.49657	.0326	.5
.6	.99057	.97878	.15242	.67441	.34040	.03842	.0077	.49654	.0327	.6
.7	.99050	.97862	.15297	.67447	.34045	.03857	.0078	.49652	.0328	.7
.8	.99043	.97846	.15353	.67452	.34051	.03871	.0078	.49649	.0329	.8
.9	.99036	.97830	.15408	.67458	.34056	.03885	.0079	.49647	.0330	.9
27.0	.99029	.97814	.15464	.67465	.34062	.03899	.0080	.49644	.0331	27.0
.1	.99022	.97798	.15519	.67471	.34067	.03913	.0080	.49641	.0333	.1
.2	.99014	.97782	.15575	.67477	.34073	.03928	.0081	.49639	.0334	.2
.3	.99007	.97766	.15630	.67483	.34079	.03942	.0081	.49636	.0335	.3
.4	.99000	.97749	.15686	.67489	.34084	.03956	.0082	.49633	.0336	.4
.5	.98993	.97733	.15741	.67495	.34090	.03970	.0082	.49631	.0337	.5
.6	.98985	.97717	.15796	.67501	.34095	.03985	.0083	.49628	.0338	.6
.7	.98978	.97700	.15852	.67507	.34101	.03999	.0084	.49625	.0339	.7
.8	.98971	.97684	.15907	.67514	.34107	.04013	.0084	.49623	.0340	.8
.9	.98963	.97667	.15962	.67520	.34113	.04027	.0085	.49620	.0342	.9
28.0	.98956	.97651	.16018	.67526	.34118	.04041	.0085	.49617	.0343	28.0
.1	.98948	.97634	.16073	.67532	.34124	.04056	.0086	.49615	.0344	.1
.2	.98941	.97617	.16128	.67539	.34130	.04070	.0087	.49612	.0345	.2
.3	.98933	.97601	.16183	.67545	.34136	.04084	.0087	.49609	.0346	.3
.4	.98926	.97584	.16239	.67551	.34141	.04098	.0088	.49606	.0347	.4
.5	.98918	.97567	.16294	.67558	.34147	.04113	.0088	.49604	.0348	.5
.6	.98911	.97550	.16349	.67564	.34153	.04127	.0089	.49601	.0349	.6
.7	.98903	.97533	.16404	.67571	.34159	.04151	.0090	.49598	.0351	.7
.8	.98895	.97516	.16459	.67577	.34165	.04155	.0090	.49595	.0352	.8
.9	.98888	.97499	.16514	.67584	.34171	.04169	.0091	.49592	.0353	.9
29.0	.98880	.97482	.16569	.67590	.34177	.04184	.0092	.49590	.0354	29.0
.1	.98872	.97465	.16624	.67597	.34183	.04198	.0092	.49587	.0355	.1
.2	.98865	.97447	.16679	.67603	.34189	.04212	.0093	.49584	.0356	.2
.3	.98857	.97430	.16734	.67610	.34195	.04226	.0093	.49581	.0357	.3
.4	.98849	.97413	.16789	.67616	.34201	.04240	.0094	.49578	.0358	.4
.5	.98841	.97395	.16844	.67623	.34207	.04254	.0095	.49575	.0359	.5
.6	.98833	.97378	.16899	.67630	.34213	.04269	.0095	.49573	.0361	.6
.7	.98826	.97360	.16954	.67636	.34219	.04283	.0096	.49570	.0362	.7
.8	.98818	.97343	.17009	.67643	.34225	.04297	.0097	.49567	.0363	.8
.9	.98810	.97325	.17064	.67650	.34232	.04311	.0097	.49564	.0364	.9

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
30 0°	.98802	.97307	.17119	.67657	.34238	.04325	.0098	.49561	.0365	30.0°
.1	.98794	.97290	.17174	.67668	.34244	.04339	.0098	.49558	.0366	.1
.2	.98786	.97272	.17229	.67670	.34250	.04354	.0099	.49555	.0367	.2
.3	.98778	.97254	.17283	.67677	.34257	.04368	.0100	.49552	.0368	.3
.4	.98770	.97236	.17338	.67684	.34263	.04382	.0100	.49549	.0369	.4
.5	.98762	.97218	.17393	.67691	.34269	.04396	.0101	.49546	.0371	.5
.6	.98754	.97200	.17448	.67698	.34276	.04410	.0102	.49543	.0372	.6
.7	.98745	.97182	.17502	.67705	.34282	.04424	.0102	.49540	.0373	.7
.8	.98737	.97164	.17557	.67712	.34288	.04439	.0103	.49537	.0374	.8
.9	.98729	.97146	.17612	.67719	.34295	.04453	.0104	.49534	.0375	.9
31.0	.98721	.97127	.17666	.67726	.34301	.04467	.0104	.49531	.0376	31.0
.1	.98713	.97109	.17721	.67733	.34308	.04481	.0105	.49528	.0377	.1
.2	.98704	.97091	.17776	.67740	.34314	.04495	.0106	.49525	.0378	.2
.3	.98696	.97072	.17830	.67747	.34321	.04509	.0106	.49522	.0379	.3
.4	.98688	.97054	.17885	.67754	.34327	.04523	.0107	.49519	.0380	.4
.5	.98680	.97035	.17939	.67761	.34334	.04538	.0108	.49516	.0381	.5
.6	.98671	.97017	.17994	.67768	.34340	.04552	.0108	.49513	.0383	.6
.7	.98663	.96998	.18048	.67775	.34347	.04566	.0109	.49510	.0384	.7
.8	.98654	.96979	.18103	.67783	.34353	.04580	.0110	.49507	.0385	.8
.9	.98646	.96960	.18157	.67790	.34360	.04594	.0110	.49504	.0386	.9
32.0	.98637	.96942	.18212	.67797	.34367	.04608	.0111	.49501	.0387	32.0
.1	.98629	.96923	.18266	.67804	.34373	.04622	.0112	.49498	.0388	.1
.2	.98620	.96904	.18320	.67812	.34380	.04636	.0112	.49495	.0389	.2
.3	.98612	.96885	.18375	.67819	.34387	.04650	.0113	.49491	.0390	.3
.4	.98603	.96866	.18429	.67826	.34394	.04665	.0114	.49488	.0391	.4
.5	.98595	.96847	.18483	.67834	.34400	.04679	.0114	.49485	.0392	.5
.6	.98586	.96827	.18538	.67841	.34407	.04693	.0115	.49482	.0393	.6
.7	.98577	.96808	.18592	.67849	.34414	.04707	.0116	.49479	.0394	.7
.8	.98569	.96789	.18646	.67856	.34421	.04721	.0116	.49476	.0395	.8
.9	.98560	.96770	.18700	.67864	.34428	.04735	.0117	.49473	.0397	.9
33.0	.98551	.96750	.18754	.67871	.34435	.04749	.0118	.49469	.0398	33.0
.1	.98543	.96731	.18809	.67879	.34442	.04763	.0118	.49466	.0399	.1
.2	.98534	.96712	.18863	.67886	.34448	.04777	.0119	.49463	.0400	.2
.3	.98525	.96692	.18917	.67894	.34455	.04791	.0120	.49460	.0401	.3
.4	.98516	.96672	.18971	.67901	.34462	.04805	.0121	.49457	.0402	.4
.5	.98507	.96653	.19025	.67909	.34469	.04820	.0121	.49453	.0403	.5
.6	.98499	.96633	.19079	.67917	.34477	.04834	.0122	.49450	.0404	.6
.7	.98490	.96613	.19133	.67925	.34484	.04848	.0123	.49447	.0405	.7
.8	.98481	.96593	.19187	.67932	.34491	.04862	.0123	.49443	.0406	.8
.9	.98472	.96574	.19241	.67940	.34498	.04876	.0124	.49440	.0407	.9
34.0	.98463	.96554	.19295	.67948	.34505	.04890	.0125	.49437	.0408	34.0
.1	.98454	.96534	.19349	.67956	.34512	.04904	.0126	.49434	.0409	.1
.2	.98445	.96514	.19403	.67963	.34519	.04918	.0126	.49430	.0410	.2
.3	.98436	.96494	.19457	.67971	.34527	.04932	.0127	.49427	.0411	.3
.4	.98427	.96473	.19510	.67979	.34534	.04946	.0128	.49424	.0412	.4
.5	.98417	.96453	.19564	.67987	.34541	.04960	.0128	.49420	.0413	.5
.6	.98408	.96433	.19618	.67995	.34548	.04974	.0129	.49417	.0415	.6
.7	.98399	.96413	.19672	.68003	.34556	.04988	.0130	.49414	.0416	.7
.8	.98390	.96392	.19726	.68011	.34563	.05002	.0131	.49410	.0417	.8
.9	.98381	.96372	.19779	.68019	.34570	.05016	.0131	.49407	.0418	.9
35.0	.98371	.96351	.19833	.68027	.34578	.05030	.0132	.49404	.0419	35.0
.1	.98362	.96331	.19887	.68035	.34585	.05044	.0133	.49400	.0420	.1
.2	.98353	.96310	.19940	.68043	.34593	.05058	.0133	.49397	.0421	.2
.3	.98344	.96290	.19994	.68051	.34600	.05072	.0134	.49393	.0422	.3
.4	.98334	.96269	.20047	.68059	.34608	.05086	.0135	.49390	.0423	.4
.5	.98325	.96248	.20101	.68068	.34615	.05100	.0136	.49387	.0424	.5
.6	.98315	.96227	.20155	.68076	.34623	.05115	.0136	.49383	.0425	.6
.7	.98306	.96207	.20208	.68084	.34630	.05129	.0137	.49380	.0426	.7
.8	.98297	.96186	.20262	.68092	.34638	.05143	.0138	.49376	.0427	.8
.9	.98287	.96165	.20315	.68101	.34645	.05157	.0139	.49373	.0428	.9

SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
36.0°	.98278	.96144	.20368	.68109	.34653	.05171	.0139	.49369	.0429	36.0°
.1	.98268	.96123	.20422	.68117	.34661	.05185	.0140	.49366	.0430	.1
.2	.98259	.96102	.20475	.68126	.34668	.05190	.0141	.49362	.0431	.2
.3	.98249	.96080	.20529	.68134	.34676	.05213	.0142	.49359	.0432	.3
.4	.98239	.96059	.20582	.68142	.34684	.05227	.0142	.49355	.0433	.4
.5	.98230	.96038	.20635	.68151	.34692	.05241	.0143	.49352	.0434	.5
.6	.98220	.96017	.20689	.68159	.34699	.05255	.0144	.49348	.0435	.6
.7	.98210	.95995	.20742	.68168	.34707	.05269	.0145	.49345	.0436	.7
.8	.98201	.95974	.20795	.68176	.34715	.05282	.0145	.49341	.0437	.8
.9	.98191	.95952	.20848	.68185	.34723	.05296	.0146	.49338	.0438	.9
37.0	.98181	.95931	.20901	.68194	.34731	.05310	.0147	.49334	.0439	37.0
.1	.98171	.95909	.20955	.68202	.34739	.05324	.0148	.49331	.0440	.1
.2	.98162	.95887	.21008	.68211	.34747	.05338	.0149	.49327	.0441	.2
.3	.98152	.95866	.21061	.68219	.34754	.05352	.0149	.49323	.0442	.3
.4	.98142	.95844	.21114	.68228	.34762	.05366	.0150	.49320	.0443	.4
.5	.98132	.95822	.21167	.68237	.34770	.05380	.0151	.49316	.0444	.5
.6	.98122	.95800	.21220	.68246	.34779	.05394	.0152	.49312	.0445	.6
.7	.98112	.95778	.21273	.68254	.34787	.05408	.0152	.49309	.0446	.7
.8	.98102	.95756	.21326	.68263	.34795	.05422	.0153	.49305	.0447	.8
.9	.98092	.95734	.21379	.68272	.34803	.05436	.0154	.49302	.0448	.9
38.0	.98082	.95712	.21432	.68281	.34811	.05450	.0155	.49298	.0449	38.0
.1	.98072	.95690	.21485	.68290	.34819	.05464	.0156	.49294	.0450	.1
.2	.98062	.95668	.21537	.68299	.34827	.05478	.0156	.49291	.0451	.2
.3	.98052	.95646	.21590	.68307	.34835	.05492	.0157	.49287	.0452	.3
.4	.98042	.95623	.21643	.68316	.34844	.05506	.0158	.49283	.0453	.4
.5	.98032	.95601	.21696	.68325	.34852	.05520	.0159	.49279	.0454	.5
.6	.98022	.95578	.21749	.68334	.34860	.05534	.0159	.49276	.0455	.6
.7	.98011	.95556	.21801	.68343	.34869	.05548	.0160	.49272	.0456	.7
.8	.98001	.95533	.21854	.68353	.34877	.05561	.0161	.49268	.0457	.8
.9	.97991	.95511	.21907	.68362	.34885	.05575	.0162	.49265	.0458	.9
39.0	.97981	.95488	.21959	.68371	.34894	.05589	.0163	.49261	.0459	39.0
.1	.97970	.95466	.22012	.68380	.34902	.05603	.0163	.49257	.0460	.1
.2	.97960	.95443	.22065	.68389	.34911	.05617	.0164	.49253	.0461	.2
.3	.97950	.95420	.22117	.68398	.34919	.05631	.0165	.49250	.0462	.3
.4	.97939	.95397	.22170	.68408	.34928	.05645	.0166	.49246	.0463	.4
.5	.97929	.95374	.22222	.68417	.34936	.05659	.0167	.49242	.0464	.5
.6	.97919	.95351	.22275	.68426	.34945	.05673	.0168	.49238	.0465	.6
.7	.97908	.95328	.22327	.68435	.34953	.05687	.0168	.49234	.0466	.7
.8	.97898	.95305	.22379	.68445	.34962	.05701	.0169	.49231	.0467	.8
.9	.97887	.95282	.22432	.68454	.34970	.05714	.0170	.49227	.0468	.9
40.0	.97877	.95259	.22484	.68464	.34979	.05728	.0171	.49223	.0469	40.0
.1	.97866	.95236	.22536	.68473	.34988	.05742	.0172	.49219	.0470	.1
.2	.97855	.95213	.22589	.68483	.34997	.05756	.0172	.49215	.0471	.2
.3	.97845	.95189	.22641	.68492	.35005	.05770	.0173	.49211	.0472	.3
.4	.97834	.95166	.22694	.68502	.35014	.05784	.0174	.49207	.0473	.4
.5	.97824	.95143	.22746	.68511	.35023	.05798	.0175	.49204	.0474	.5
.6	.97813	.95119	.22798	.68521	.35032	.05812	.0176	.49200	.0475	.6
.7	.97802	.95096	.22850	.68530	.35040	.05825	.0177	.49196	.0476	.7
.8	.97791	.95072	.22902	.68540	.35049	.05839	.0177	.49192	.0477	.8
.9	.97781	.95048	.22954	.68550	.35058	.05853	.0178	.49188	.0478	.9
41.0	.97770	.95025	.23006	.68559	.35067	.05867	.0179	.49184	.0479	41.0
.1	.97759	.95001	.23058	.68569	.35076	.05881	.0180	.49180	.0480	.1
.2	.97748	.94977	.23110	.68579	.35085	.05895	.0181	.49176	.0481	.2
.3	.97737	.94953	.23162	.68588	.35094	.05909	.0182	.49172	.0482	.3
.4	.97727	.94929	.23214	.68598	.35103	.05922	.0182	.49168	.0483	.4
.5	.97716	.94906	.23266	.68608	.35112	.05936	.0183	.49164	.0484	.5
.6	.97705	.94882	.23318	.68618	.35121	.05950	.0184	.49160	.0485	.6
.7	.97694	.94857	.23370	.68628	.35130	.05964	.0185	.49156	.0486	.7
.8	.97683	.94833	.23422	.68638	.35139	.05978	.0186	.49152	.0487	.8
.9	.97672	.94809	.23473	.68648	.35149	.05992	.0187	.49148	.0488	.9

382 TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
42.0°	.97661	.94785	.23525	.68658	.35158	.06005	.0187	.49144	.0488	42.0°
.1	.97650	.94761	.23577	.68668	.35167	.06019	.0188	.49140	.0489	.1
.2	.97639	.94736	.23629	.68678	.35176	.06033	.0189	.49136	.0490	.2
.3	.97628	.94712	.23680	.68688	.35186	.06047	.0190	.49132	.0491	.3
.4	.97616	.94688	.23732	.68698	.35195	.06061	.0191	.49128	.0492	.4
.5	.97605	.94663	.23784	.68708	.35204	.06074	.0192	.49124	.0493	.5
.6	.97594	.94639	.23835	.68718	.35214	.06088	.0193	.49120	.0494	.6
.7	.97583	.94614	.23887	.68728	.35223	.06102	.0193	.49116	.0495	.7
.8	.97572	.94590	.23938	.68738	.35232	.06116	.0194	.48112	.0496	.8
.9	.97560	.94565	.23990	.68749	.35242	.06130	.0195	.49108	.0497	.9
43.0	.97549	.94540	.24041	.68759	.35251	.06143	.0196	.49103	.0498	43.0
.1	.97538	.94515	.24093	.68769	.35261	.06157	.0197	.49099	.0499	.1
.2	.97526	.94491	.24144	.68780	.35270	.06171	.0198	.49095	.0500	.2
.3	.97515	.94466	.24196	.68790	.35280	.06185	.0199	.49091	.0501	.3
.4	.97504	.94441	.24247	.68800	.35289	.06198	.0200	.49087	.0502	.4
.5	.97492	.94416	.24298	.68811	.35299	.06212	.0200	.49083	.0503	.5
.6	.97481	.94391	.24349	.68821	.35309	.06226	.0201	.49079	.0503	.6
.7	.97469	.94366	.24401	.68832	.35318	.06240	.0202	.49074	.0504	.7
.8	.97458	.94340	.24452	.68842	.35328	.06253	.0203	.49070	.0505	.8
.9	.97446	.94315	.24503	.68853	.35338	.06267	.0204	.49066	.0506	.9
44.0	.97435	.94290	.24554	.68863	.35347	.06281	.0205	.49062	.0507	44.0
.1	.97423	.94265	.24606	.68874	.35357	.06295	.0206	.49058	.0508	.1
.2	.97412	.94239	.24657	.68884	.35367	.06308	.0207	.49053	.0509	.2
.3	.97400	.94214	.24708	.68895	.35377	.06322	.0208	.49049	.0510	.3
.4	.97388	.94189	.24759	.68906	.35387	.06336	.0208	.49045	.0511	.4
.5	.97377	.94163	.24810	.68917	.35397	.06350	.0209	.49041	.0512	.5
.6	.97365	.94138	.24861	.68927	.35407	.06363	.0210	.49036	.0513	.6
.7	.97353	.94112	.24912	.68938	.35416	.06377	.0211	.49032	.0514	.7
.8	.97342	.94086	.24963	.68949	.35426	.06391	.0212	.49028	.0514	.8
.9	.97330	.94061	.25014	.68960	.35436	.06405	.0213	.49024	.0515	.9
45.0	.97318	.94035	.25064	.68971	.35446	.06418	.0214	.49019	.0516	45.0

TABLE L.—RADI, DEFLECTIONS, AND
CHORDS. ARC DEFINITION

Degree of Curve	Radius of Curve	Deflection for 1 Ft. of Arc	Deflec- tion for 25' of Arc	Deflection for 50' of Arc	Chord for 25' of Arc	Chord for 50' of Arc	Chord for 100' of Arc
0 30	11,459.16	00.15	.....	0 07.5	.....	50.00	100.00
40	8,594.37	00.2	.....	0 10.0	.....	50.00	100.00
50	6,875.50	00.25	.....	0 12.5	.....	50.00	100.00
1 0	5,729.58	00.3	.....	0 15.0	.....	50.00	100.00
10	4,911.07	00.35	.....	0 17.5	.....	50.00	100.00
20	4,297.18	00.4	.....	0 20.0	.....	50.00	100.00
30	3,819.72	00.45	.....	0 22.5	.....	50.00	100.00
40	3,437.75	00.5	.....	0 25.0	.....	50.00	100.00
50	3,125.23	00.55	.....	0 27.5	.....	50.00	100.00
2 0	2,864.79	00.6	.....	0 30.0	.....	50.00	100.00
10	2,644.42	00.65	.....	0 32.5	.....	50.00	99.99
20	2,455.53	00.7	.....	0 35.0	.....	50.00	99.99
30	2,291.83	00.75	.....	0 37.5	.....	50.00	99.99
40	2,148.59	00.8	.....	0 40.0	.....	50.00	99.99
50	2,022.20	00.85	.....	0 42.5	.....	50.00	99.99
3 0	1,909.86	00.9	.....	0 45.0	.....	50.00	99.99
10	1,809.34	00.95	.....	0 47.5	.....	50.00	99.99
20	1,718.87	01.0	.....	0 50.0	.....	50.00	99.99
30	1,637.02	01.05	.....	0 52.5	.....	50.00	99.98
40	1,562.61	01.1	.....	0 55.0	.....	50.00	99.98
50	1,494.67	01.15	.....	0 57.5	.....	50.00	99.98
4 0	1,432.40	01.2	.....	1 00.0	.....	50.00	99.98
10	1,375.10	01.25	.....	1 02.5	.....	50.00	99.98
20	1,322.21	01.3	.....	1 05.0	.....	50.00	99.98
30	1,273.24	01.35	.....	1 07.5	.....	50.00	99.97
40	1,227.77	01.4	.....	1 10.0	.....	50.00	99.97
50	1,185.43	01.45	.....	1 12.5	.....	50.00	99.97
5 0	1,145.92	01.5	.....	1 15.0	.....	50.00	99.97
10	1,108.95	01.55	.....	1 17.5	.....	50.00	99.97
20	1,074.30	01.6	.....	1 20.0	.....	50.00	99.96
30	1,041.74	01.65	.....	1 22.5	.....	50.00	99.96
40	1,011.10	01.7	.....	1 25.0	.....	50.00	99.96
50	982.21	01.75	.....	1 27.5	.....	50.00	99.96
6 0	954.93	01.8	.....	1 30.0	.....	50.00	99.95
10	929.12	01.85	.....	1 32.5	.....	50.00	99.95
20	904.67	01.9	.....	1 35.0	.....	50.00	99.95
30	881.47	01.95	.....	1 37.5	.....	50.00	99.95
40	859.44	02.0	.....	1 40.0	.....	50.00	99.94
50	838.47	02.05	.....	1 42.5	.....	50.00	99.94
7 0	818.51	02.1	.....	1 45.0	.....	50.00	99.94
10	799.48	02.15	.....	1 47.5	.....	49.99	99.94
20	781.31	02.2	.....	1 50.0	.....	49.99	99.93
30	763.94	02.25	.....	1 52.5	.....	49.99	99.93
40	747.34	02.3	.....	1 55.0	.....	49.99	99.93
50	731.44	02.35	.....	1 57.5	.....	49.99	99.92
8 0	716.20	02.4	.....	2 00.0	.....	49.99	99.92
10	701.58	02.45	.....	2 02.5	.....	49.99	99.92
20	687.55	02.5	.....	2 05.0	.....	49.99	99.91
30	674.07	02.55	.....	2 07.5	.....	49.99	99.91
40	661.11	02.6	.....	2 10.0	.....	49.99	99.90
50	648.63	02.65	.....	2 12.5	.....	49.99	99.90
9 0	636.62	02.7	.....	2 15.0	.....	49.99	99.90
10	625.04	02.75	.....	2 17.5	.....	49.99	99.89
20	613.88	02.8	.....	2 20.0	.....	49.99	99.89
30	603.11	02.85	.....	2 22.5	.....	49.99	99.89
40	592.72	02.9	.....	2 25.0	.....	49.99	99.88
50	582.67	02.95	.....	2 27.5	.....	49.98	99.88
10 0	572.96	03.0	.....	2 30.0	.....	49.98	99.88

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 25' of Arc	Deflec- tion for 50' of Arc	Chord for 25' of Arc	Chord for 50' of Arc	Chord for 100' of Arc
0 /		/	0 /	0 /			
10 0	572.96	03.0	.....	2 30.0	.....	49.98	99.87
10 10	563.56	03.05	.....	2 32.5	.....	49.98	99.87
20 20	554.48	03.1	.....	2 35.0	.....	49.98	99.86
30 30	545.68	03.15	.....	2 37.5	.....	49.98	99.86
40 40	537.15	03.2	.....	2 40.0	.....	49.98	99.86
50 50	528.88	03.25	.....	2 42.5	.....	49.98	99.85
11 0	520.87	03.3	.....	2 45.0	.....	49.98	99.85
10 10	513.10	03.35	.....	2 47.5	.....	49.98	99.84
20 20	505.55	03.4	.....	2 50.0	.....	49.98	99.84
30 30	498.22	03.45	.....	2 52.5	.....	49.98	99.83
40 40	491.11	03.5	.....	2 55.0	.....	49.98	99.83
50 50	484.19	03.55	.....	2 57.5	.....	49.98	99.82
12 0	477.46	03.6	.....	3 00.0	.....	49.98	99.82
10 10	470.92	03.65	.....	3 02.5	.....	49.98	99.81
20 20	464.56	03.7	.....	3 05.0	.....	49.98	99.81
30 30	458.37	03.75	.....	3 07.5	.....	49.98	99.80
40 40	452.34	03.8	.....	3 10.0	.....	49.98	99.80
50 50	446.46	03.85	.....	3 12.5	.....	49.98	99.79
13 0	440.74	03.9	.....	3 15.0	.....	49.97	99.79
10 10	435.16	03.95	.....	3 17.5	.....	49.97	99.78
20 20	429.72	04.0	.....	3 20.0	.....	49.97	99.77
30 30	424.41	04.05	.....	3 22.5	.....	49.97	99.77
40 40	419.24	04.1	.....	3 25.0	.....	49.97	99.76
50 50	414.19	04.15	.....	3 27.5	.....	49.97	99.76
14 0	409.26	04.2	.....	3 30.0	.....	49.97	99.75
10 10	404.44	04.25	.....	3 32.5	.....	49.97	99.75
20 20	399.74	04.3	.....	3 35.0	.....	49.97	99.74
30 30	395.14	04.35	.....	3 37.5	.....	49.97	99.73
40 40	390.65	04.4	.....	3 40.0	.....	49.97	99.73
50 50	386.26	04.45	.....	3 42.5	.....	49.97	99.72
15 0	381.97	04.5	.....	3 45.0	.....	49.96	99.72
10 10	377.77	04.55	.....	3 47.5	.....	49.96	99.71
20 20	373.67	04.6	.....	3 50.0	.....	49.96	99.70
30 30	369.65	04.65	.....	3 52.5	.....	49.96	99.70
40 40	365.72	04.7	.....	3 55.0	.....	49.96	99.69
50 50	361.87	04.75	.....	3 57.5	.....	49.96	99.68
16 0	358.10	04.8	2 00.0	4 00.0	.....	49.96	99.68
10 10	354.41	04.85	2 01.2	4 02.5	.....	49.96	99.67
20 20	350.79	04.9	2 02.5	4 05.0	.....	49.96	99.66
30 30	347.25	04.95	2 03.8	4 07.5	.....	49.96	99.65
40 40	343.77	05.0	2 05.0	4 10.0	.....	49.96	99.65
50 50	340.37	05.05	2 06.2	4 12.5	.....	49.96	99.64
17 0	337.03	05.1	2 07.5	4 15.0	.....	49.95	99.63
10 10	333.76	05.15	2 08.8	4 17.5	.....	49.95	99.63
20 20	330.55	05.2	2 10.0	4 20.0	.....	49.95	99.62
30 30	327.40	05.25	2 11.2	4 22.5	.....	49.95	99.61
40 40	324.32	05.3	2 12.5	4 25.0	.....	49.95	99.60
50 50	321.28	05.35	2 13.8	4 27.5	.....	49.95	99.60
18 0	318.31	05.4	2 15.0	4 30.0	24.99	49.95	99.59
10 10	315.39	05.45	2 16.2	4 32.5	24.99	49.95	99.58
20 20	312.52	05.5	2 17.5	4 35.0	24.99	49.95	99.57
30 30	309.71	05.55	2 18.8	4 37.5	24.99	49.95	99.57
40 40	306.94	05.6	2 20.0	4 40.0	24.99	49.94	99.56
50 50	304.22	05.65	2 21.2	4 42.5	24.99	49.94	99.55
19 0	301.56	05.7	2 22.5	4 45.0	24.99	49.94	99.54
10 10	298.93	05.75	2 23.7	4 47.5	24.99	49.94	99.53
20 20	296.36	05.8	2 25.0	4 50.0	24.99	49.94	99.53
30 30	293.82	05.85	2 26.2	4 52.5	24.99	49.94	99.52
40 40	291.33	05.9	2 27.5	4 55.0	24.99	49.94	99.51
50 50	288.89	05.95	2 28.8	4 57.5	24.99	49.94	99.50
20 0	286.48	06.0	2 30.0	5 00.0	24.99	49.94	99.49

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 25' of Arc	Deflec- tion for 50' of Arc	Chord for 25' of Arc	Chord for 50' of Arc	Chord for 100' of Arc
° /		'	° /	° /	of Arc	of Arc	of Arc
20	0	286.48	06.0	2 30.0	5 00.0	24.99	49.94
	10	284.11	06.05	2 31.3	5 02.5	24.99	49.94
	20	281.78	06.1	2 32.5	5 05.0	24.99	49.94
	30	279.49	06.15	2 33.8	5 07.5	24.99	49.94
	40	277.24	06.2	2 35.0	5 10.0	24.99	49.94
	50	275.02	06.25	2 36.3	5 12.5	24.99	49.94
21	0	272.84	06.3	2 37.5	5 15.0	24.99	49.93
	10	270.69	06.35	2 38.7	5 17.5	24.99	49.93
	20	268.57	06.4	2 40.0	5 20.0	24.99	49.93
	30	266.49	06.45	2 41.3	5 22.5	24.99	49.93
	40	264.44	06.5	2 42.5	5 25.0	24.99	49.92
	50	262.42	06.55	2 43.7	5 27.5	24.99	49.92
22	0	260.44	06.6	2 45.0	5 30.0	24.99	49.92
	10	258.48	06.65	2 46.3	5 32.5	24.99	49.92
	20	256.55	06.7	2 47.5	5 35.0	24.99	49.92
	30	254.65	06.75	2 48.7	5 37.5	24.99	49.92
	40	252.78	06.8	2 50.0	5 40.0	24.99	49.92
	50	250.93	06.85	2 51.3	5 42.5	24.99	49.92
23	0	249.11	06.9	2 52.5	5 45.0	24.99	49.92
	10	247.32	06.95	2 53.8	5 47.5	24.99	49.91
	20	245.55	07.0	2 55.0	5 50.0	24.99	49.91
	30	243.81	07.05	2 56.3	5 52.5	24.99	49.91
	40	242.09	07.1	2 57.5	5 55.0	24.99	49.91
	50	240.40	07.15	2 58.7	5 57.5	24.99	49.91
24	0	238.73	07.2	3 00.0	6 00.0	24.99	49.91
	10	237.09	07.25	3 01.3	6 02.5	24.99	49.91
	20	235.46	07.3	3 02.5	6 05.0	24.99	49.91
	30	233.86	07.35	3 03.8	6 07.5	24.99	49.90
	40	232.28	07.4	3 05.0	6 10.0	24.99	49.90
	50	230.72	07.45	3 06.3	6 12.5	24.99	49.90
25	0	229.18	07.5	3 07.5	6 15.0	24.99	49.90
	10	227.66	07.55	3 08.7	6 17.5	24.99	49.90
	20	226.17	07.6	3 10.0	6 20.0	24.99	49.90
	30	224.69	07.65	3 11.3	6 22.5	24.99	49.90
	40	223.23	07.7	3 12.5	6 25.0	24.99	49.90
	50	221.79	07.75	3 13.8	6 27.5	24.99	49.89
26	0	220.37	07.8	3 15.0	6 30.0	24.99	49.89
	10	218.96	07.85	3 16.3	6 32.5	24.99	49.89
	20	217.58	07.9	3 17.5	6 35.0	24.99	49.89
	30	216.21	07.95	3 18.8	6 37.5	24.99	49.89
	40	214.86	08.0	3 20.0	6 40.0	24.99	49.89
	50	213.52	08.05	3 21.3	6 42.5	24.99	49.89
27	0	212.21	08.1	3 22.5	6 45.0	24.99	49.88
	10	210.90	08.15	3 23.8	6 47.5	24.99	49.88
	20	209.62	08.2	3 25.0	6 50.0	24.99	49.88
	30	208.35	08.25	3 26.3	6 52.5	24.98	49.88
	40	207.09	08.3	3 27.5	6 55.0	24.98	49.88
	50	205.85	08.35	3 28.8	6 57.5	24.98	49.88
28	0	204.63	08.4	3 30.0	7 00.0	24.98	49.88
	10	203.42	08.45	3 31.3	7 02.5	24.98	49.87
	20	202.22	08.5	3 32.5	7 05.0	24.98	49.87
	30	201.04	08.55	3 33.8	7 07.5	24.98	49.87
	40	199.87	08.6	3 35.0	7 10.0	24.98	49.87
	50	198.71	08.65	3 36.3	7 12.5	24.98	49.87
29	0	197.57	08.7	3 37.5	7 15.0	24.98	49.87
	10	196.44	08.75	3 38.8	7 17.5	24.98	49.87
	20	195.33	08.8	3 40.0	7 20.0	24.98	49.87
	30	194.22	08.85	3 41.3	7 22.5	24.98	49.87
	40	193.13	08.9	3 42.5	7 25.0	24.98	49.87
	50	192.05	08.95	3 43.8	7 27.5	24.98	49.87
30	0	190.99	09.0	3 45.0	7 30.0	24.98	49.86

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
° /		° /	° /	° /			
30 0	190.99	09.0	1 30.0	3 45.0	10.00	24.98	98.86
10	189.93	09.05	1 30.5	3 46.3	10.00	24.98	98.85
20	188.89	09.1	1 31.0	3 47.5	10.00	24.98	98.84
30	187.86	09.15	1 31.5	3 48.8	10.00	24.98	98.82
40	186.83	09.2	1 32.0	3 50.0	10.00	24.98	98.81
50	185.82	09.25	1 32.5	3 51.3	10.00	24.98	98.80
31 0	184.82	09.3	1 33.0	3 52.5	10.00	24.98	98.79
10	183.84	09.35	1 33.5	3 53.8	10.00	24.98	98.77
20	182.86	09.4	1 34.0	3 55.0	10.00	24.98	98.76
30	181.89	09.45	1 34.5	3 56.3	10.00	24.98	98.75
40	180.93	09.5	1 35.0	3 57.5	10.00	24.98	98.73
50	179.99	09.55	1 35.5	3 58.8	10.00	24.98	98.72
32 0	179.05	09.6	1 36.0	4 00.0	10.00	24.98	98.71
10	178.12	09.65	1 36.5	4 01.3	10.00	24.98	98.69
20	177.20	09.7	1 37.0	4 02.5	10.00	24.98	98.68
30	176.29	09.75	1 37.5	4 03.8	10.00	24.98	98.66
40	175.40	09.8	1 38.0	4 05.0	10.00	24.98	98.65
50	174.50	09.85	1 38.5	4 06.3	10.00	24.98	98.64
33 0	173.62	09.9	1 39.0	4 07.5	10.00	24.98	98.62
10	172.75	09.95	1 39.5	4 08.7	10.00	24.98	98.61
20	171.89	10.0	1 40.0	4 10.0	10.00	24.98	98.60
30	171.03	10.05	1 40.5	4 11.3	10.00	24.98	98.58
40	170.18	10.1	1 41.0	4 12.5	10.00	24.98	98.57
50	169.35	10.15	1 41.5	4 13.8	10.00	24.98	98.55
34 0	168.52	10.2	1 42.0	4 15.0	10.00	24.98	98.54
10	167.70	10.25	1 42.5	4 16.3	10.00	24.98	98.53
20	166.88	10.3	1 43.0	4 17.5	10.00	24.98	98.51
30	166.07	10.35	1 43.5	4 18.8	10.00	24.98	98.50
40	165.28	10.4	1 44.0	4 20.0	10.00	24.98	98.48
50	164.48	10.45	1 44.5	4 21.3	10.00	24.98	98.47
35 0	163.70	10.5	1 45.0	4 22.5	10.00	24.98	98.45
10	162.93	10.55	1 45.5	4 23.8	10.00	24.98	98.44
20	162.16	10.6	1 46.0	4 25.0	10.00	24.98	98.42
30	161.40	10.65	1 46.5	4 26.3	10.00	24.98	98.41
40	160.64	10.7	1 47.0	4 27.5	10.00	24.97	98.39
50	159.90	10.75	1 47.5	4 28.8	10.00	24.97	98.38
36 0	159.16	10.8	1 48.0	4 30.0	10.00	24.97	98.36
10	158.42	10.85	1 48.5	4 31.3	10.00	24.97	98.35
20	157.69	10.9	1 49.0	4 32.5	10.00	24.97	98.33
30	156.97	10.95	1 49.5	4 33.8	10.00	24.97	98.32
40	156.26	11.0	1 50.0	4 35.0	10.00	24.97	98.30
50	155.55	11.05	1 50.5	4 36.3	10.00	24.97	98.29
37 0	154.85	11.1	1 51.0	4 37.5	10.00	24.97	98.27
10	154.16	11.15	1 51.5	4 38.8	10.00	24.97	98.26
20	153.47	11.2	1 52.0	4 40.0	10.00	24.97	98.24
30	152.79	11.25	1 52.5	4 41.3	10.00	24.97	98.22
40	152.11	11.3	1 53.0	4 42.5	10.00	24.97	98.21
50	151.44	11.35	1 53.5	4 43.8	10.00	24.97	98.19
38 0	150.78	11.4	1 54.0	4 45.0	10.00	24.97	98.18
10	150.12	11.45	1 54.5	4 46.3	10.00	24.97	98.16
20	149.47	11.5	1 55.0	4 47.5	10.00	24.97	98.15
30	148.82	11.55	1 55.5	4 48.7	10.00	24.97	98.13
40	148.18	11.6	1 56.0	4 50.0	10.00	24.97	98.11
50	147.54	11.65	1 56.5	4 51.3	10.00	24.97	98.10
39 0	146.91	11.7	1 57.0	4 52.5	10.00	24.97	98.08
10	146.29	11.75	1 57.5	4 53.8	10.00	24.97	98.06
20	145.67	11.8	1 58.0	4 55.0	10.00	24.97	98.05
30	145.05	11.85	1 58.5	4 56.3	10.00	24.97	98.03
40	144.44	11.9	1 59.0	4 57.5	10.00	24.97	98.02
50	143.84	11.95	1 59.5	4 58.8	10.00	24.97	98.00
40 0	143.24	12.0	2 00.0	5 00.0	10.00	24.97	97.98

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
° /		'	° /	° /			
40 0	143.24	12.0	2 00.0	5 00.0	10.00	24.97	97.98
10	142.64	12.05	2 00.5	5 01.3	10.00	24.97	97.97
20	142.06	12.1	2 01.0	5 02.5	10.00	24.97	97.95
30	141.47	12.15	2 01.5	5 03.8	10.00	24.97	97.93
40	140.89	12.2	2 02.0	5 05.0	10.00	24.97	97.91
50	140.32	12.25	2 02.5	5 06.3	10.00	24.97	97.90
41 0	139.74	12.3	2 03.0	5 07.5	10.00	24.97	97.88
10	139.18	12.35	2 03.5	5 08.8	10.00	24.97	97.86
20	138.62	12.4	2 04.0	5 10.0	10.00	24.97	97.85
30	138.06	12.45	2 04.5	5 11.3	10.00	24.97	97.83
40	137.51	12.5	2 05.0	5 12.5	10.00	24.97	97.81
50	136.96	12.55	2 05.5	5 13.8	10.00	24.97	97.79
42 0	136.42	12.6	2 06.0	5 15.0	10.00	24.97	97.78
10	135.88	12.65	2 06.5	5 16.3	10.00	24.96	97.76
20	135.34	12.7	2 07.0	5 17.5	10.00	24.96	97.74
30	134.81	12.75	2 07.5	5 18.8	10.00	24.96	97.72
40	134.29	12.8	2 08.0	5 20.0	10.00	24.96	97.71
50	133.76	12.85	2 08.5	5 21.3	10.00	24.96	97.69
43 0	133.25	12.9	2 09.0	5 22.5	10.00	24.96	97.67
10	132.73	12.95	2 09.5	5 23.8	10.00	24.96	97.65
20	132.22	13.0	2 10.0	5 25.0	10.00	24.96	97.63
30	131.71	13.05	2 10.5	5 26.3	10.00	24.96	97.62
40	131.21	13.10	2 11.0	5 27.5	10.00	24.96	97.60
50	130.71	13.15	2 11.5	5 28.8	10.00	24.96	97.58
44 0	130.22	13.2	2 12.0	5 30.0	10.00	24.96	97.56
10	129.73	13.25	2 12.5	5 31.3	10.00	24.96	97.54
20	129.24	13.3	2 13.0	5 32.5	10.00	24.96	97.52
30	128.75	13.35	2 13.5	5 33.8	10.00	24.96	97.51
40	128.27	13.4	2 14.0	5 35.0	10.00	24.96	97.49
50	127.80	13.45	2 14.5	5 36.3	10.00	24.96	97.47
45 0	127.32	13.5	2 15.0	5 37.5	10.00	24.96	97.45
10	126.85	13.55	2 15.5	5 38.8	10.00	24.96	97.43
20	126.39	13.6	2 16.0	5 40.0	10.00	24.96	97.41
30	125.92	13.65	2 16.5	5 41.3	10.00	24.96	97.39
40	125.46	13.7	2 17.0	5 42.5	10.00	24.96	97.37
50	125.01	13.75	2 17.5	5 43.8	10.00	24.96	97.36
46 0	124.56	13.8	2 18.0	5 45.0	10.00	24.96	97.34
10	124.11	13.85	2 18.5	5 46.3	10.00	24.96	97.32
20	123.66	13.9	2 19.0	5 47.5	10.00	24.96	97.30
30	123.22	13.95	2 19.5	5 48.8	10.00	24.96	97.28
40	122.78	14.0	2 20.0	5 50.0	10.00	24.96	97.26
50	122.34	14.05	2 20.5	5 51.3	10.00	24.96	97.24
47 0	121.91	14.1	2 21.0	5 52.5	10.00	24.96	97.22
10	121.48	14.15	2 21.5	5 53.8	10.00	24.96	97.20
20	121.05	14.2	2 22.0	5 55.0	10.00	24.96	97.19
30	120.62	14.25	2 22.5	5 56.3	10.00	24.96	97.16
40	120.20	14.3	2 23.0	5 57.5	10.00	24.95	97.14
50	119.78	14.35	2 23.5	5 58.8	10.00	24.95	97.12
48 0	119.38	14.4	2 24.0	6 00.0	10.00	24.95	97.10
10	118.95	14.45	2 24.5	6 01.3	10.00	24.95	97.08
20	118.54	14.5	2 25.0	6 02.5	10.00	24.95	97.06
30	118.13	14.55	2 25.5	6 03.8	10.00	24.95	97.04
40	117.73	14.6	2 26.0	6 05.0	10.00	24.95	97.02
50	117.33	14.65	2 26.5	6 06.3	10.00	24.95	97.00
49 0	116.93	14.7	2 27.0	6 07.5	10.00	24.95	96.98
10	116.53	14.75	2 27.5	6 08.8	10.00	24.95	96.96
20	116.14	14.8	2 28.0	6 10.0	10.00	24.95	96.94
30	115.75	14.85	2 28.5	6 11.3	10.00	24.95	96.92
40	115.36	14.9	2 29.0	6 12.5	10.00	24.95	96.90
50	114.97	14.95	2 29.5	6 13.8	10.00	24.95	96.88
50 0	114.59	15.0	2 30.0	6 15.0	10.00	24.95	96.86

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
° /		/	° /	° /			
50 00	114.59	15.0	2 30.0	6° 15.0	10.00	24.95	96.86
10	114.21	15.05	2 30.5	6 16.3	10.00	24.95	96.84
20	113.83	15.1	2 31.0	6 17.5	10.00	24.95	96.82
30	113.46	15.15	2 31.5	6 18.8	10.00	24.95	96.79
40	113.08	15.2	2 32.0	6 20.0	10.00	24.95	96.77
50	112.71	15.25	2 32.5	6 21.3	10.00	24.95	96.75
51 0	112.34	15.3	2 33.0	6 22.5	10.00	24.95	96.73
10	111.98	15.35	2 33.5	6 23.8	10.00	24.95	96.71
20	111.62	15.4	2 34.0	6 25.0	10.00	24.95	96.69
30	111.26	15.45	2 34.5	6 26.3	10.00	24.95	96.67
40	110.90	15.5	2 35.0	6 27.5	10.00	24.95	96.65
50	110.54	15.55	2 35.5	6 28.8	10.00	24.95	96.63
52 0	110.18	15.6	2 36.0	6 30.0	10.00	24.95	96.60
10	109.83	15.65	2 36.5	6 31.3	10.00	24.95	96.58
20	109.48	15.7	2 37.0	6 32.5	10.00	24.95	96.56
30	109.14	15.75	2 37.5	6 33.8	10.00	24.95	96.54
40	108.79	15.8	2 38.0	6 35.0	10.00	24.94	96.52
50	108.45	15.85	2 38.5	6 36.3	10.00	24.94	96.49
53 0	108.11	15.9	2 39.0	6 37.5	10.00	24.94	96.47
10	107.77	15.95	2 39.5	6 38.8	10.00	24.94	96.45
20	107.43	16.0	2 40.0	6 40.0	10.00	24.94	96.43
30	107.09	16.05	2 40.5	6 41.3	10.00	24.94	96.41
40	106.76	16.1	2 41.0	6 42.5	10.00	24.94	96.38
50	106.43	16.15	2 41.5	6 43.8	10.00	24.94	96.36
54 0	106.10	16.2	2 42.0	6 45.0	10.00	24.94	96.34
10	105.78	16.25	2 42.5	6 46.3	10.00	24.94	96.32
20	105.45	16.3	2 43.0	6 47.5	10.00	24.94	96.30
30	105.13	16.35	2 43.5	6 48.8	10.00	24.94	96.27
40	104.81	16.4	2 44.0	6 50.0	10.00	24.94	96.25
50	104.49	16.45	2 44.5	6 51.3	10.00	24.94	96.23
55 0	104.17	16.5	2 45.0	6 52.5	10.00	24.94	96.21
10	103.86	16.55	2 45.5	6 53.8	10.00	24.94	96.18
20	103.55	16.6	2 46.0	6 55.0	10.00	24.94	96.16
30	103.24	16.65	2 46.5	6 56.3	10.00	24.94	96.14
40	102.93	16.7	2 47.0	6 57.5	10.00	24.94	96.11
50	102.62	16.75	2 47.5	6 58.8	10.00	24.94	96.09
56 0	102.32	16.8	2 48.0	7 00.0	10.00	24.94	96.07
10	102.01	16.85	2 48.5	7 01.3	10.00	24.94	96.04
20	101.71	16.9	2 49.0	7 02.5	10.00	24.94	96.02
30	101.41	16.95	2 49.5	7 03.8	10.00	24.94	96.00
40	101.11	17.0	2 50.0	7 05.0	10.00	24.94	95.97
50	100.81	17.05	2 50.5	7 06.3	10.00	24.94	95.95
57 0	100.52	17.1	2 51.0	7 07.5	10.00	24.94	95.93
10	100.22	17.15	2 51.5	7 08.8	10.00	24.94	95.90
20	99.93	17.2	2 52.0	7 10.0	10.00	24.94	95.88
30	99.64	17.25	2 52.5	7 11.3	10.00	24.94	95.86
40	99.36	17.3	2 53.0	7 12.5	10.00	24.94	95.83
50	99.07	17.35	2 53.5	7 13.8	10.00	24.94	95.81
58 0	98.79	17.4	2 54.0	7 15.0	10.00	24.94	95.79
10	98.50	17.45	2 54.5	7 16.3	10.00	24.94	95.76
20	98.22	17.5	2 55.0	7 17.5	10.00	24.94	95.74
30	97.94	17.55	2 55.5	7 18.7	10.00	24.94	95.71
40	97.66	17.6	2 56.0	7 20.0	10.00	24.94	95.69
50	97.39	17.65	2 56.5	7 21.3	10.00	24.94	95.66
59 0	97.11	17.7	2 57.0	7 22.5	10.00	24.94	95.64
10	96.84	17.75	2 57.5	7 23.8	10.00	24.93	95.62
20	96.56	17.8	2 58.0	7 25.0	10.00	24.93	95.59
30	96.30	17.85	2 58.5	7 26.3	10.00	24.93	95.57
40	96.03	17.9	2 59.0	7 27.5	10.00	24.93	95.54
50	95.76	16.95	2 59.5	7 28.8	10.00	24.93	95.52
60 0	95.49	18.0	3 00.0	7 30.0	10.00	24.93	95.49

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
° /		'	° /	° /			
60 0	95.49	18.0	3 00.0	7 30.0	10.00	24.93	95.49
10	95.23	18.05	3 00.5	7 31.3	10.00	24.93	95.47
20	94.96	18.1	3 01.0	7 32.5	10.00	24.93	95.44
30	94.70	18.15	3 01.5	7 33.8	10.00	24.93	95.42
40	94.44	18.2	3 02.0	7 35.0	10.00	24.93	95.39
50	94.18	18.25	3 02.5	7 36.3	10.00	24.93	95.37
61 0	93.92	18.3	3 03.0	7 37.5	10.00	24.93	95.34
10	93.67	18.35	3 03.5	7 38.8	10.00	24.93	95.32
20	93.42	18.4	3 04.0	7 40.0	10.00	24.93	95.29
30	93.16	18.45	3 04.5	7 41.3	10.00	24.93	95.27
40	92.91	18.5	3 05.0	7 42.5	10.00	24.92	95.24
50	92.66	18.55	3 05.5	7 43.8	10.00	24.92	95.22
62 0	92.41	18.6	3 06.0	7 45.0	10.00	24.92	95.19
10	92.16	18.65	3 06.5	7 46.3	10.00	24.92	95.16
20	91.92	18.7	3 07.0	7 47.5	10.00	24.92	95.14
30	91.67	18.75	3 07.5	7 48.8	10.00	24.92	95.12
40	91.43	18.8	3 08.0	7 50.0	10.00	24.92	95.09
50	91.19	18.85	3 08.5	7 51.3	10.00	24.92	95.06
63 0	90.94	18.9	3 09.0	7 52.5	10.00	24.92	95.04
10	90.71	18.95	3 09.5	7 53.8	10.00	24.92	95.01
20	90.47	19.0	3 10.0	7 55.0	10.00	24.92	94.99
30	90.23	19.05	3 10.5	7 56.3	10.00	24.92	94.96
40	89.99	19.1	3 11.0	7 57.5	10.00	24.92	94.93
50	89.76	19.15	3 11.5	7 58.8	10.00	24.92	94.91
64 0	89.52	19.2	3 12.0	8 00.0	10.00	24.92	94.88
10	89.29	19.25	3 12.5	8 01.3	10.00	24.92	94.86
20	89.06	19.3	3 13.0	8 02.5	10.00	24.92	94.83
30	88.83	19.35	3 13.5	8 03.8	10.00	24.92	94.80
40	88.60	19.4	3 14.0	8 05.0	10.00	24.92	94.78
50	88.37	19.45	3 14.5	8 06.3	10.00	24.92	94.75
65 0	88.15	19.5	3 15.0	8 07.5	10.00	24.92	94.72
10	87.92	19.55	3 15.5	8 08.8	10.00	24.92	94.70
20	87.70	19.6	3 16.0	8 10.0	10.00	24.92	94.67
30	87.47	19.65	3 16.5	8 11.3	10.00	24.92	94.64
40	87.25	19.7	3 17.0	8 12.5	10.00	24.91	94.62
50	87.03	19.75	3 17.5	8 13.8	10.00	24.91	94.59
66 0	86.81	19.8	3 18.0	8 15.0	10.00	24.91	94.56
10	86.59	19.85	3 18.5	8 16.3	10.00	24.91	94.54
20	86.38	19.9	3 19.0	8 17.5	10.00	24.91	94.51
30	86.16	19.95	3 19.5	8 18.8	10.00	24.91	94.48
40	85.94	20.0	3 20.0	8 20.0	10.00	24.91	94.45
50	85.73	20.05	3 20.5	8 21.3	10.00	24.91	94.43
67 00	85.52	20.1	3 21.0	8 22.5	10.00	24.91	94.40
10	85.30	20.15	3 21.5	8 23.8	10.00	24.91	94.37
20	85.09	20.2	3 22.0	8 25.0	10.00	24.91	94.34
30	84.88	20.25	3 22.5	8 26.3	10.00	24.91	94.32
40	84.67	20.3	3 23.0	8 27.5	10.00	24.91	94.29
50	84.46	20.35	3 23.5	8 28.8	10.00	24.91	94.26
68 0	84.26	20.4	3 24.0	8 30.0	10.00	24.91	94.23
10	84.05	20.45	3 24.5	8 31.3	9.99	24.91	94.21
20	83.85	20.5	3 25.0	8 32.5	9.99	24.91	94.18
30	83.64	20.55	3 25.5	8 33.8	9.99	24.91	94.15
40	83.44	20.6	3 26.0	8 35.0	9.99	24.91	94.12
50	83.24	20.65	3 26.5	8 36.3	9.99	24.91	94.10
69 0	83.04	20.7	3 27.0	8 37.5	9.99	24.91	94.07
10	82.84	20.75	3 27.5	8 38.8	9.99	24.91	94.04
20	82.64	20.8	3 28.0	8 40.0	9.99	24.90	94.01
30	82.44	20.85	3 28.5	8 41.3	9.99	24.90	93.98
40	82.24	20.9	3 29.0	8 42.5	9.99	24.90	93.95
50	82.05	20.95	3 29.5	8 43.8	9.99	24.90	93.92
70 0	81.85	21.0	3 30.0	8 45.0	9.99	24.90	93.90

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
70 0	81.85	21.0	3 30.0	8 45.0	9.99	24.90	93.90
10	81.66	21.05	3 30.5	8 46.3	9.99	24.90	93.87
20	81.46	21.1	3 31.0	8 47.5	9.99	24.90	93.84
30	81.27	21.15	3 31.5	8 48.8	9.99	24.90	93.81
40	81.08	21.2	3 32.0	8 50.0	9.99	24.90	93.78
50	80.89	21.25	3 32.5	8 51.3	9.99	24.90	93.75
71 0	80.70	21.3	3 33.0	8 52.5	9.99	24.90	93.72
10	80.51	21.35	3 33.5	8 53.8	9.99	24.90	93.69
20	80.32	21.4	3 34.0	8 55.0	9.99	24.90	93.67
30	80.13	21.45	3 34.5	8 56.3	9.99	24.90	93.64
40	79.95	21.5	3 35.0	8 57.5	9.99	24.90	93.61
50	79.76	21.55	3 35.5	8 58.8	9.99	24.90	93.58
72 0	79.58	21.6	3 36.0	9 00.0	9.99	24.90	93.55
10	79.39	21.65	3 36.5	9 01.3	9.99	24.90	93.52
20	79.21	21.7	3 37.0	9 02.5	9.99	24.90	93.49
30	79.03	21.75	3 37.5	9 03.8	9.99	24.90	93.46
40	78.85	21.8	3 38.0	9 05.0	9.99	24.90	93.43
50	78.67	21.85	3 38.5	9 06.3	9.99	24.89	93.40
73 0	78.49	21.9	3 39.0	9 07.5	9.99	24.89	93.37
10	78.31	21.95	3 39.5	9 08.8	9.99	24.89	93.34
20	78.13	22.0	3 40.0	9 10.0	9.99	24.89	93.31
30	77.95	22.05	3 40.5	9 11.3	9.99	24.89	93.28
40	77.78	22.1	3 41.0	9 12.5	9.99	24.89	93.25
50	77.60	22.15	3 41.5	9 13.8	9.99	24.89	93.22
74 0	77.43	22.2	3 42.0	9 15.0	9.99	24.89	93.19
10	77.25	22.25	3 42.5	9 16.3	9.99	24.89	93.16
20	77.08	22.3	3 43.0	9 17.5	9.99	24.89	93.13
30	76.91	22.35	3 43.5	9 18.8	9.99	24.89	93.10
40	76.74	22.4	3 44.0	9 20.0	9.99	24.89	93.07
50	76.56	22.45	3 44.5	9 21.3	9.99	24.89	93.04
75 0	76.39	22.5	3 45.0	9 22.5	9.99	24.89	93.01
10	76.22	22.55	3 45.5	9 23.8	9.99	24.89	92.98
20	76.06	22.6	3 46.0	9 25.0	9.99	24.89	92.95
30	75.89	22.65	3 46.5	9 26.3	9.99	24.89	92.92
40	75.82	22.7	3 47.0	9 27.5	9.99	24.89	92.89
50	75.55	22.75	3 47.5	9 28.8	9.99	24.89	92.86
76 0	75.39	22.8	3 48.0	9 30.0	9.99	24.89	92.83
10	75.22	22.85	3 48.5	9 31.3	9.99	24.89	92.80
20	75.06	22.9	3 49.0	9 32.5	9.99	24.88	92.77
30	74.90	22.95	3 49.5	9 33.8	9.99	24.88	92.74
40	74.73	23.0	3 50.0	9 35.0	9.99	24.88	92.71
50	74.57	23.05	3 50.5	9 36.3	9.99	24.88	92.67
77 0	74.41	23.1	3 51.0	9 37.5	9.99	24.88	92.64
10	74.25	23.15	3 51.5	9 38.8	9.99	24.88	92.61
20	74.09	23.2	3 52.0	9 40.0	9.99	24.88	92.58
30	73.93	23.25	3 52.5	9 41.3	9.99	24.88	92.55
40	73.77	23.3	3 53.0	9 42.5	9.99	24.88	92.51
50	73.61	23.35	3 53.5	9 43.8	9.99	24.88	92.49
78 0	73.46	23.4	3 54.0	9 45.0	9.99	24.88	92.46
10	73.30	23.45	3 54.5	9 46.3	9.99	24.88	92.42
20	73.14	23.5	3 55.0	9 47.5	9.99	24.88	92.39
30	72.99	23.55	3 55.5	9 48.8	9.99	24.88	92.36
40	72.83	23.6	3 56.0	9 50.0	9.99	24.88	92.33
50	72.68	23.65	3 56.5	9 51.3	9.99	24.88	92.30
79 0	72.53	23.7	3 57.0	9 52.5	9.99	24.88	92.27
10	72.37	23.75	3 57.5	9 53.8	9.99	24.88	92.23
20	72.22	23.8	3 58.0	9 55.0	9.99	24.88	92.20
30	72.07	23.85	3 58.5	9 56.3	9.99	24.88	92.17
40	71.92	23.9	3 59.0	9 57.5	9.99	24.88	92.14
50	71.77	23.95	3 59.5	9 58.8	9.99	24.88	92.11
80 0	71.62	24.0	4 00.0	10 00.0	9.99	24.87	92.07

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
80 0	71.62	24.0	4 00.0	10 00.0	9.99	24.87	92.07
10	71.47	24.05	4 00.5	10 01.3	9.99	24.87	92.04
20	71.32	24.1	4 01.0	10 02.5	9.99	24.87	92.01
30	71.17	24.15	4 01.5	10 03.8	9.99	24.87	91.98
40	71.03	24.2	4 02.0	10 05.0	9.99	24.87	91.94
50	70.88	24.25	4 02.5	10 06.3	9.99	24.87	91.91
81 0	70.74	24.3	4 03.0	10 07.5	9.99	24.87	91.88
10	70.59	24.35	4 03.5	10 08.8	9.99	24.87	91.85
20	70.44	24.4	4 04.0	10 10.0	9.99	24.87	91.81
30	70.30	24.45	4 04.5	10 11.3	9.99	24.87	91.78
40	70.16	24.5	4 05.0	10 12.5	9.99	24.87	91.75
50	70.02	24.55	4 05.5	10 13.8	9.99	24.87	91.71
82 0	69.87	24.6	4 06.0	10 15.0	9.99	24.87	91.68
10	69.73	24.65	4 06.5	10 16.3	9.99	24.87	91.65
20	69.59	24.7	4 07.0	10 17.5	9.99	24.87	91.62
30	69.45	24.75	4 07.5	10 18.8	9.99	24.87	91.58
40	69.31	24.8	4 08.0	10 20.0	9.99	24.86	91.55
50	69.17	24.85	4 08.5	10 21.3	9.99	24.86	91.52
83 0	69.03	24.9	4 09.0	10 22.5	9.99	24.86	91.48
10	68.89	24.95	4 09.5	10 23.8	9.99	24.86	91.45
20	68.75	25.0	4 10.0	10 25.0	9.99	24.86	91.42
30	68.62	25.05	4 10.5	10 26.3	9.99	24.86	91.38
40	68.48	25.1	4 11.0	10 27.5	9.99	24.86	91.35
50	68.34	25.15	4 11.5	10 28.8	9.99	24.86	91.32
84 0	68.21	25.2	4 12.0	10 30.0	9.99	24.86	91.28
10	68.07	25.25	4 12.5	10 31.3	9.99	24.86	91.25
20	67.94	25.3	4 13.0	10 32.5	9.99	24.86	91.21
30	67.81	25.35	4 13.5	10 33.8	9.99	24.86	91.18
40	67.67	25.4	4 14.0	10 35.0	9.99	24.86	91.15
50	67.54	25.45	4 14.5	10 36.3	9.99	24.86	91.11
85 0	67.41	25.5	4 15.0	10 37.5	9.99	24.86	91.08
10	67.27	25.55	4 15.5	10 38.8	9.99	24.86	91.05
20	67.14	25.6	4 16.0	10 40.0	9.99	24.86	91.01
30	67.01	25.65	4 16.5	10 41.3	9.99	24.86	90.98
40	66.88	25.7	4 17.0	10 42.5	9.99	24.85	90.94
50	66.75	25.75	4 17.5	10 43.8	9.99	24.85	90.91
86 0	66.62	25.8	4 18.0	10 45.0	9.99	24.85	90.87
10	66.49	25.85	4 18.5	10 46.3	9.99	24.85	90.84
20	66.36	25.9	4 19.0	10 47.5	9.99	24.85	90.80
30	66.24	25.95	4 19.5	10 48.8	9.99	24.85	90.77
40	66.11	26.0	4 20.0	10 50.0	9.99	24.85	90.74
50	65.98	26.05	4 20.5	10 51.3	9.99	24.85	90.70
87 0	65.86	26.1	4 21.0	10 52.5	9.99	24.85	90.67
10	65.73	26.15	4 21.5	10 53.8	9.99	24.85	90.63
20	65.61	26.2	4 22.0	10 55.0	9.99	24.85	90.60
30	65.48	26.25	4 22.5	10 56.3	9.99	24.85	90.56
40	65.36	26.3	4 23.0	10 57.5	9.99	24.85	90.53
50	65.23	26.35	4 23.5	10 58.8	9.99	24.85	90.49
88 0	65.11	26.4	4 24.0	11 00.0	9.99	24.85	90.46
10	64.98	26.45	4 24.5	11 01.3	9.99	24.85	90.42
20	64.86	26.5	4 25.0	11 02.5	9.99	24.85	90.39
30	64.74	26.55	4 25.5	11 03.8	9.99	24.84	90.35
40	64.62	26.6	4 26.0	11 05.0	9.99	24.84	90.32
50	64.50	26.65	4 26.5	11 06.3	9.99	24.84	90.28
89 0	64.38	26.7	4 27.0	11 07.5	9.99	24.84	90.25
10	64.26	26.75	4 27.5	11 08.8	9.99	24.84	90.21
20	64.14	26.8	4 28.0	11 10.0	9.99	24.84	90.17
30	64.02	26.85	4 28.5	11 11.3	9.99	24.84	90.14
40	63.90	26.9	4 29.0	11 12.5	9.99	24.84	90.10
50	63.78	26.95	4 29.5	11 13.8	9.99	24.84	90.07
90 0	63.66	27.0	4 30.0	11 15.0	9.99	24.84	90.03

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
° /		/	° /	° /			
90 0	63.66	27.0	4 30.0	11 15.0	9.99	24.84	90.03
10	63.54	27.05	4 30.5	11 16.3	9.99	24.84	90.00
20	63.43	27.1	4 31.0	11 17.5	9.99	24.84	89.96
30	63.31	27.15	4 31.5	11 18.8	9.99	24.84	89.92
40	63.19	27.2	4 32.0	11 20.0	9.99	24.84	89.89
50	63.08	27.25	4 32.5	11 21.3	9.99	24.84	89.85
91 0	62.96	27.3	4 33.0	11 22.5	9.99	24.84	89.82
10	62.85	27.35	4 33.5	11 23.8	9.99	24.84	89.78
20	62.73	27.4	4 34.0	11 25.0	9.99	24.83	89.74
30	62.62	27.45	4 34.5	11 26.3	9.99	24.83	89.71
40	62.50	27.5	4 35.0	11 27.5	9.99	24.83	89.67
50	62.39	27.55	4 35.5	11 28.8	9.99	24.83	89.64
92 0	62.28	27.6	4 36.0	11 30.0	9.99	24.83	89.60
10	62.16	27.65	4 36.5	11 31.3	9.99	24.83	89.56
20	62.05	27.7	4 37.0	11 32.5	9.99	24.83	89.53
30	61.94	27.75	4 37.5	11 33.8	9.99	24.83	89.49
40	61.83	27.8	4 38.0	11 35.0	9.99	24.83	89.45
50	61.72	27.85	4 38.5	11 36.3	9.99	24.83	89.42
93 0	61.61	27.9	4 39.0	11 37.5	9.99	24.83	89.38
10	61.50	27.95	4 39.5	11 38.8	9.99	24.83	89.34
20	61.39	28.0	4 40.0	11 40.0	9.99	24.83	89.30
30	61.28	28.05	4 40.5	11 41.3	9.99	24.83	89.27
40	61.17	28.1	4 41.0	11 42.5	9.99	24.83	89.23
50	61.06	28.15	4 41.5	11 43.8	9.99	24.83	89.19
94 0	60.95	28.2	4 42.0	11 45.0	9.99	24.83	89.16
10	60.84	28.25	4 42.5	11 46.3	9.99	24.82	89.12
20	60.74	28.3	4 43.0	11 47.5	9.99	24.82	89.08
30	60.63	28.35	4 43.5	11 48.8	9.99	24.82	89.04
40	60.52	28.4	4 44.0	11 50.0	9.99	24.82	89.01
50	60.42	28.45	4 44.5	11 51.3	9.99	24.82	88.97
95 0	60.31	28.5	4 45.0	11 52.5	9.99	24.82	88.93
10	60.21	28.55	4 45.5	11 53.8	9.99	24.82	88.90
20	60.10	28.6	4 46.0	11 55.0	9.99	24.82	88.86
30	60.00	28.65	4 46.5	11 56.3	9.99	24.82	88.82
40	59.89	28.7	4 47.0	11 57.5	9.99	24.82	88.78
50	59.79	28.75	4 47.5	11 58.8	9.99	24.82	88.74
96 0	59.68	28.8	4 48.0	12 00.0	9.99	24.82	88.71
10	59.58	28.85	4 48.5	12 01.3	9.99	24.82	88.67
20	59.48	28.9	4 49.0	12 02.5	9.99	24.82	88.63
30	59.37	28.95	4 49.5	12 03.8	9.99	24.82	88.59
40	59.27	29.0	4 50.0	12 05.0	9.99	24.82	88.55
50	59.17	29.05	4 50.5	12 06.3	9.99	24.81	88.52
97 0	59.07	29.1	4 51.0	12 07.5	9.99	24.81	88.48
10	58.97	29.15	4 51.5	12 08.8	9.99	24.81	88.44
20	58.86	29.2	4 52.0	12 10.0	9.99	24.81	88.40
30	58.76	29.25	4 52.5	12 11.3	9.99	24.81	88.36
40	58.66	29.3	4 53.0	12 12.5	9.99	24.81	88.33
50	58.56	29.35	4 53.5	12 13.8	9.99	24.81	88.29
98 0	58.46	29.4	4 54.0	12 15.0	9.99	24.81	88.25
10	58.36	29.45	4 54.5	12 16.3	9.99	24.81	88.21
20	58.27	29.5	4 55.0	12 17.5	9.99	24.81	88.17
30	58.17	29.55	4 55.5	12 18.8	9.99	24.81	88.13
40	58.07	29.6	4 56.0	12 20.0	9.99	24.81	88.09
50	57.97	29.65	4 56.5	12 21.3	9.99	24.81	88.06
99 0	57.87	29.7	4 57.0	12 22.5	9.99	24.81	88.02
10	57.78	29.75	4 57.5	12 23.8	9.99	24.81	87.98
20	57.68	29.8	4 58.0	12 25.0	9.99	24.80	87.94
30	57.58	29.85	4 58.5	12 26.3	9.99	24.80	87.90
40	57.49	29.9	4 59.0	12 27.5	9.99	24.80	87.86
50	57.39	29.95	4 59.5	12 28.8	9.99	24.80	87.82
100 0	57.30	30.0	5 00.0	12 30.0	9.99	24.80	87.78

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
100 0	57.30	30.0	5 00.0	12 30.0	9.99	24.80	87.78
10	57.20	30.05	5 00.5	12 31.3	9.99	24.80	87.74
20	57.11	30.1	5 01.0	12 32.5	9.99	24.80	87.70
30	57.01	30.15	5 01.5	12 33.8	9.99	24.80	87.66
40	56.92	30.2	5 02.0	12 35.0	9.99	24.80	87.63
50	56.82	30.25	5 02.5	12 36.3	9.99	24.80	87.59
101 0	56.73	30.3	5 03.0	12 37.5	9.99	24.80	87.55
10	56.64	30.35	5 03.5	12 38.8	9.99	24.80	87.51
20	56.54	30.4	5 04.0	12 40.0	9.99	24.80	87.47
30	56.45	30.45	5 04.5	12 41.3	9.99	24.80	87.43
40	56.36	30.5	5 05.0	12 42.5	9.99	24.79	87.39
50	56.26	30.55	5 05.5	12 43.8	9.99	24.79	87.35
102 0	56.17	30.6	5 06.0	12 45.0	9.99	24.79	87.31
10	56.08	30.65	5 06.5	12 46.3	9.99	24.79	87.27
20	55.99	30.7	5 07.0	12 47.5	9.99	24.79	87.23
30	55.90	30.75	5 07.5	12 48.8	9.99	24.79	87.19
40	55.81	30.8	5 08.0	12 50.0	9.99	24.79	87.15
50	55.72	30.85	5 08.5	12 51.3	9.99	24.79	87.11
103 0	55.63	30.9	5 09.0	12 52.5	9.99	24.79	87.07
10	55.54	30.95	5 09.5	12 53.8	9.99	24.79	87.03
20	55.45	31.0	5 10.0	12 55.0	9.99	24.79	86.99
30	55.36	31.05	5 10.5	12 56.3	9.99	24.79	86.95
40	55.27	31.1	5 11.0	12 57.5	9.99	24.79	86.91
50	55.18	31.15	5 11.5	12 58.8	9.99	24.79	86.87
104 0	55.09	31.2	5 12.0	13 00.0	9.99	24.79	86.83
10	55.00	31.25	5 12.5	13 01.3	9.99	24.78	86.79
20	54.92	31.3	5 13.0	13 02.5	9.99	24.78	86.75
30	54.83	31.35	5 13.5	13 03.8	9.99	24.78	86.70
40	54.74	31.4	5 14.0	13 05.0	9.99	24.78	86.66
50	54.65	31.45	5 14.5	13 06.3	9.99	24.78	86.62
105 0	54.57	31.5	5 15.0	13 07.5	9.99	24.78	86.58
10	54.48	31.55	5 15.5	13 08.8	9.99	24.78	86.54
20	54.39	31.6	5 16.0	13 10.0	9.99	24.78	86.50
30	54.31	31.65	5 16.5	13 11.3	9.99	24.78	86.46
40	54.22	31.7	5 17.0	13 12.5	9.99	24.78	86.42
50	54.14	31.75	5 17.5	13 13.8	9.99	24.78	86.38
106 0	54.05	31.8	5 18.0	13 15.0	9.99	24.78	86.34
10	53.97	31.85	5 18.5	13 16.3	9.99	24.78	86.30
20	53.88	31.9	5 19.0	13 17.5	9.99	24.78	86.25
30	53.80	31.95	5 19.5	13 18.8	9.99	24.78	86.21
40	53.71	32.0	5 20.0	13 20.0	9.99	24.77	86.17
50	53.63	32.05	5 20.5	13 21.3	9.99	24.77	86.13
107 0	53.55	32.1	5 21.0	13 22.5	9.99	24.77	86.09
10	53.46	32.15	5 21.5	13 23.8	9.99	24.77	86.05
20	53.38	32.2	5 22.0	13 25.0	9.99	24.77	86.01
30	53.30	32.25	5 22.5	13 26.3	9.99	24.77	85.96
40	53.22	32.3	5 23.0	13 27.5	9.99	24.77	85.92
50	53.13	32.35	5 23.5	13 28.8	9.99	24.77	85.88
108 0	53.05	32.4	5 24.0	13 30.0	9.99	24.77	85.84
10	52.97	32.45	5 24.5	13 31.3	9.99	24.77	85.80
20	52.89	32.5	5 25.0	13 32.5	9.99	24.77	85.76
30	52.81	32.55	5 25.5	13 33.8	9.99	24.77	85.71
40	52.73	32.6	5 26.0	13 35.0	9.99	24.77	85.67
50	52.64	32.65	5 26.5	13 36.3	9.99	24.77	85.63
109 0	52.56	32.7	5 27.0	13 37.5	9.99	24.77	85.59
10	52.48	32.75	5 27.5	13 38.8	9.99	24.77	85.55
20	52.40	32.8	5 28.0	13 40.0	9.99	24.76	85.50
30	52.32	32.85	5 28.5	13 41.3	9.98	24.76	85.46
40	52.24	32.9	5 29.0	13 42.5	9.98	24.76	85.42
50	52.17	32.95	5 29.5	13 43.8	9.98	24.76	85.38
110 0	52.09	33.0	5 30.0	13 45.0	9.98	24.76	85.33

TABLE L.—RADII, DEFLECTIONS, AND
 CHORDS. ARC DEFINITION

Degree of Curve	Radius of Curve	Deflec- tion for 1 Ft. of Arc	Deflec- tion for 10' of Arc	Deflec- tion for 25' of Arc	Chord for 10' of Arc	Chord for 25' of Arc	Chord for 100' of Arc
110 0	52.09	33.0	5 30.0	13 45.0	9.98	24.76	85.33
10	52.01	33.05	5 30.5	13 46.3	9.98	24.76	85.29
20	51.93	33.1	5 31.0	13 47.5	9.98	24.76	85.24
30	51.85	33.15	5 31.5	13 48.8	9.98	24.76	85.21
40	51.77	33.2	5 32.0	13 50.0	9.98	24.76	85.16
50	51.70	33.25	5 32.5	13 51.3	9.98	24.76	85.12
111 0	51.62	33.3	5 33.0	13 52.5	9.98	24.76	85.08
10	51.54	33.35	5 33.5	13 53.8	9.98	24.76	85.04
20	51.46	33.4	5 34.0	13 55.0	9.98	24.76	84.99
30	51.39	33.45	5 34.5	13 56.3	9.98	24.75	84.95
40	51.31	33.5	5 35.0	13 57.5	9.98	24.75	84.91
50	51.23	33.55	5 35.5	13 58.8	9.98	24.75	84.86
112 0	51.16	33.6	5 36.0	14 00.0	9.98	24.75	84.82
10	51.08	33.65	5 36.5	14 01.3	9.98	24.75	84.78
20	51.01	33.7	5 37.0	14 02.5	9.98	24.75	84.74
30	50.93	33.75	5 37.5	14 03.8	9.98	24.75	84.69
40	50.85	33.8	5 38.0	14 05.0	9.98	24.75	84.65
50	50.78	33.85	5 38.5	14 06.3	9.98	24.75	84.61
113 0	50.70	33.9	5 39.0	14 07.5	9.98	24.75	84.56
10	50.63	33.95	5 39.5	14 08.8	9.98	24.75	84.52
20	50.56	34.0	5 40.0	14 10.0	9.98	24.75	84.48
30	50.48	34.05	5 40.5	14 11.3	9.98	24.75	84.43
40	50.41	34.1	5 41.0	14 12.5	9.98	24.74	84.39
50	50.33	34.15	5 41.5	14 13.8	9.98	24.74	84.35
114 0	50.26	34.2	5 42.0	14 15.0	9.98	24.74	84.30
10	50.19	34.25	5 42.5	14 16.3	9.98	24.74	84.26
20	50.11	34.3	5 43.0	14 17.5	9.98	24.74	84.22
30	50.04	34.35	5 43.5	14 18.8	9.98	24.74	84.17
40	49.97	34.4	5 44.0	14 20.0	9.98	24.74	84.13
50	49.89	34.45	5 44.5	14 21.3	9.98	24.74	84.08
115 0	49.82	34.5	5 45.0	14 22.5	9.98	24.74	84.04
10	49.75	34.55	5 45.5	14 23.8	9.98	24.74	84.00
20	49.68	34.6	5 46.0	14 25.0	9.98	24.74	83.95
30	49.61	34.65	5 46.5	14 26.3	9.93	24.74	83.91
40	49.54	34.7	5 47.0	14 27.5	9.98	24.74	83.86
50	49.46	34.75	5 47.5	14 28.8	9.98	24.73	83.82
116 0	49.39	34.8	5 48.0	14 30.0	9.98	24.73	83.78
10	49.32	34.85	5 48.5	14 31.3	9.98	24.73	83.73
20	49.25	34.9	5 49.0	14 32.5	9.98	24.73	83.69
30	49.18	34.95	5 49.5	14 33.8	9.98	24.73	83.64
40	49.11	35.0	5 50.0	14 35.0	9.98	24.73	83.60
50	49.04	35.05	5 50.5	14 36.3	9.98	24.73	83.55
117 0	48.97	35.1	5 51.0	14 37.5	9.98	24.73	83.51
10	48.90	35.15	5 51.5	14 38.8	9.98	24.73	83.46
20	48.83	35.2	5 52.0	14 40.0	9.98	24.73	83.42
30	48.76	35.25	5 52.5	14 41.3	9.98	24.73	83.38
40	48.69	35.3	5 53.0	14 42.5	9.98	24.73	83.33
50	48.62	35.35	5 53.5	14 43.8	9.98	24.73	83.29
118 0	48.56	35.4	5 54.0	14 45.0	9.98	24.72	83.24
10	48.49	35.45	5 54.5	14 46.3	9.98	24.72	83.20
20	48.42	35.5	5 55.0	14 47.5	9.98	24.72	83.15
30	48.35	35.55	5 55.5	14 48.8	9.98	24.72	83.11
40	48.28	35.6	5 56.0	14 50.0	9.98	24.72	83.06
50	48.22	35.65	5 56.5	14 51.3	9.98	24.72	83.02
119 0	48.15	35.7	5 57.0	14 52.5	9.98	24.72	82.97
10	48.08	35.75	5 57.5	14 53.8	9.98	24.72	82.93
20	48.01	35.8	5 58.0	14 55.0	9.98	24.72	82.88
30	47.95	35.85	5 58.5	14 56.3	9.98	24.72	82.84
40	47.88	35.9	5 59.0	14 57.5	9.98	24.72	82.79
50	47.81	35.95	5 59.5	14 58.8	9.98	24.72	82.75
120 0	47.75	36.0	6 00.0	15 00.0	9.98	24.72	82.70

TABLE LI.—EVEN FOOT RADII.
DEFLECTIONS AND CHORDS

Radius	Deflection for 1 Ft. of Arc	Length of Arc	Deflection for Particular Arc	Chord for Particular Arc
15	114.5916	10	19 05.92	9.82
20	85.9437	10	14 19.44	9.90
25	68.7549	10	11 27.56	9.93
30	57.2958	10	9 32.96	9.95
35	49.1107	10	8 11.10	9.96
40	42.9718	10	7 09.72	9.97
45	38.1972	10	6 21.98	9.98
50	34.3775	10	5 43.78	9.98
55	31.2522	10	5 12.52	9.99
60	28.6479	10	4 46.48	9.99
65	26.4442	10	4 24.44	9.99
70	24.5553	10	4 05.55	9.99
75	22.9183	10	3 49.18	9.99
80	21.4859	10	3 34.86	10.00
85	20.2220	10	3 22.22	10.00
90	19.0986	10	3 10.99	10.00
95	18.0934	10	3 00.94	10.00
100	17.1887	25	7 09.72	24.93
110	15.6261	25	6 30.65	24.95
120	14.3239	25	5 58.10	24.96
130	13.2221	25	5 30.55	24.96
140	12.2777	25	5 06.94	24.96
150	11.4592	25	4 46.48	24.97
160	10.7430	25	4 28.58	24.97
170	10.1110	25	4 12.77	24.97
180	9.5493	25	3 58.73	24.98
190	9.0467	25	3 46.17	24.98
200	8.5944	25	3 34.85	24.98
225	7.6394	25	3 10.99	24.99
250	6.8755	25	2 51.89	24.99
275	6.2504	25	2 36.26	24.99
300	5.7296	50	4 46.48	49.94
325	5.2888	50	4 24.44	49.95
350	4.9111	50	4 05.56	49.96
375	4.5837	50	3 49.18	49.96
400	4.2972	50	3 34.86	49.97
450	3.8197	50	3 10.99	49.97
500	3.4377	50	2 51.89	49.98
550	3.1252	50	2 36.26	49.98
600	2.8648	50	2 23.24	49.99
650	2.6444	50	2 12.22	50.00
700	2.4555	100	4 05.56	99.92
750	2.2918	100	3 49.19	99.93
800	2.1486	100	3 34.86	99.93
850	2.0222	100	3 22.22	99.94
900	1.9099	100	3 10.99	99.95
950	1.8093	100	3 00.93	99.95
1,000	1.7189	100	2 51.89	99.96
1,100	1.5626	100	2 36.26	99.96
1,200	1.4324	100	2 23.24	99.97
1,300	1.3222	100	2 12.22	99.97
1,400	1.2278	100	2 02.78	99.98
1,500	1.1459	100	1 54.59	99.98
1,600	1.0743	100	1 47.43	99.98
1,700	1.0111	100	1 41.11	99.99
1,800	0.95493	100	1 35.49	99.99
1,900	0.90467	100	1 30.47	100.00
2,000	0.85944	100	1 25.95	100.00

TABLE LI.—EVEN FOOT RADII.
DEFLECTIONS AND CHORDS

Radius	Deflection for 1 Ft. of Arc	Length of Arc	Deflection for 100 Ft. Arc	Chord for 100 Ft. Arc
2,100	0.81851	100	1 21.85	100.00
2,200	0.78131	100	1 18.13	100.00
2,300	0.74734	100	1 14.73	100.00
2,400	0.71620	100	1 11.62	100.00
2,500	0.68755	100	1 08.75	100.00
2,600	0.66111	100	1 06.11	100.00
2,700	0.63662	100	1 03.66	100.00
2,800	0.61388	100	1 01.38	100.00
2,900	0.59271	100	0 59.27	100.00
3,000	0.57296	100	0 57.29	100.00
3,100	0.55448	100	0 55.44	100.00
3,200	0.53715	100	0 53.71	100.00
3,300	0.52087	100	0 52.09	100.00
3,400	0.50555	100	0 50.55	100.00
3,500	0.49111	100	0 49.11	100.00
3,600	0.47746	100	0 47.74	100.00
3,700	0.46456	100	0 46.45	100.00
3,800	0.45234	100	0 45.23	100.00
3,900	0.44074	100	0 44.07	100.00
4,000	0.42972	100	0 42.97	100.00
4,100	0.41924	100	0 41.92	100.00
4,200	0.40926	100	0 40.93	100.00
4,300	0.39974	100	0 39.08	100.00
4,400	0.39065	100	0 39.06	100.00
4,500	0.38197	100	0 38.20	100.00
4,600	0.37367	100	0 37.37	100.00
4,700	0.36572	100	0 36.54	100.00
4,800	0.35810	100	0 35.81	100.00
4,900	0.35079	100	0 35.08	100.00
5,000	0.34377	100	0 34.38	100.00
5,100	0.33703	100	0 33.70	100.00
5,200	0.33055	100	0 33.06	100.00
5,300	0.32432	100	0 32.43	100.00
5,400	0.31831	100	0 31.83	100.00
5,500	0.31252	100	0 31.25	100.00
5,600	0.30694	100	0 30.69	100.00
5,700	0.30156	100	0 30.16	100.00
5,800	0.29636	100	0 29.64	100.00
5,900	0.29133	100	0 29.13	100.00
6,000	0.28648	100	0 28.65	100.00
6,100	0.28178	100	0 28.18	100.00
6,200	0.27724	100	0 27.72	100.00
6,300	0.27284	100	0 27.29	100.00
6,400	0.26857	100	0 26.86	100.00
6,500	0.26444	100	0 26.44	100.00
6,600	0.26044	100	0 26.04	100.00
6,700	0.25655	100	0 25.65	100.00
6,800	0.25278	100	0 25.28	100.00
6,900	0.24911	100	0 24.91	100.00
7,000	0.24555	100	0 24.55	100.00
8,000	0.21486	100	0 21.486	100.00
9,000	0.19099	100	0 19.099	100.00
10,000	0.17189	100	0 17.189	100.00
11,000	0.15626	100	0 15.626	100.00
12,000	0.14324	100	0 14.324	100.00
13,000	0.13222	100	0 13.222	100.00
14,000	0.12278	100	0 12.278	100.00
15,000	0.11459	100	0 11.459	100.00
16,000	0.10743	100	0 10.743	100.00
17,000	0.10111	100	0 10.111	100.00
18,000	0.095493	100	0 09.5493	100.00
19,000	0.090467	100	0 09.0467	100.00
20,000	0.085944	100	0 08.5944	100.00

TABLE LII.—COEFFICIENT *K* FOR CENTRAL
ANGLES OF CERTAIN CURVES

Radius	Coefficient <i>K</i>	Radius	Coefficient <i>K</i>
15	229.183 1180	1700	2.022 2040
20	171.887 3385	1800	1.909 8593
25	137.509 8708	1900	1.809 3404
30	114.591 5590	2000	1.718 8734
35	98.221 3363	2100	1.637 0223
40	85.943 6693	2200	1.562 6122
45	76.394 3727	2300	1.494 6725
50	68.754 9354	2400	1.432 3945
55	62.504 4867	2500	1.375 0987
60	57.295 7795	2600	1.322 2103
65	52.888 4118	2700	1.273 2395
70	49.110 6682	2800	1.227 7667
75	45.836 6236	2900	1.185 4299
80	42.971 8346	3000	1.145 9156
85	40.444 0796	3100	1.108 9506
90	38.197 1863	3200	1.074 2959
95	36.186 8081	3300	1.041 7414
100	34.377 4677	3400	1.011 1020
110	31.252 2433	3500	0.982 2134
120	28.647 8898	3600	0.954 9297
130	26.444 2059	3700	0.929 1207
140	24.555 3341	3800	0.904 6702
150	22.918 3118	3900	0.881 4735
160	21.485 9173	4000	0.859 4367
170	20.222 0398	4100	0.838 4751
180	19.098 5932	4200	0.818 5111
190	18.093 4041	4300	0.799 4760
200	17.188 7339	4400	0.781 3061
225	15.278 8745	4500	0.763 9437
250	13.750 9871	4600	0.747 3363
275	12.500 8973	4700	0.731 4355
300	11.459 1559	4800	0.716 1972
325	10.577 6824	4900	0.701 5810
350	9.822 1336	5000	0.687 5493
375	9.167 3247	5100	0.674 0680
400	8.594 3669	5200	0.661 1051
450	7.639 4373	5300	0.648 6315
500	6.875 4935	5400	0.636 6198
550	6.250 4487	5500	0.625 0449
600	5.729 5780	5600	0.613 8834
650	5.288 8412	5700	0.603 1135
700	4.911 0668	5800	0.592 7150
750	4.583 6624	5900	0.582 6689
800	4.297 1835	6000	0.572 9578
850	4.044 4080	6100	0.563 5650
900	3.819 7186	6200	0.554 4753
950	3.618 6808	6300	0.545 6741
1000	3.437 7468	6400	0.537 1479
1100	3.125 2243	6500	0.528 8841
1200	2.864 7890	6600	0.520 8707
1300	2.644 4206	6700	0.513 0965
1400	2.455 5334	6800	0.505 5510
1500	2.291 8312	6900	0.498 2242
1600	2.148 5917	7000	0.491 1067

EXPLANATION OF TABLES

TABLE I. Contains the radius and its logarithm for every degree of curve to single minutes up to 10° , and thence by larger intervals up to 50° . With the radius is given also the perpendicular offset t from the tangent to a point on the curve at the end of the first 100-ft chord from the tangent point, and the middle ordinate m of a 100-ft chord.

TABLE II. Contains the corrections to be added to the tangents and externals of any railroad curve, as obtained by reference to Table III, according to the degree of the given curve (found at head of columns), and its central angle (found in the first column). If the given degree of curve or central angle does not appear in the table, the exact value of the correction may be easily obtained by interpolation.

TABLE III. Contains the exact values of the tangents, T , and externals, E , to a 1° curve, for every $10'$ of central angle, from 1° to $120^\circ 50'$. Approximate values of the tangent and external to any other degree of curve may be found by simply dividing the tabular values opposite the given central angle by the given degree of curve, expressed in degrees. These approximations may be made exact by adding the proper corrections taken from Table II. See equations 17 and 20.

TABLE IV. Contains the value of long chords of from 2 to 12 stations, for every $10'$ of degree of curve from 0° to 15° , and of a smaller number of stations for degrees of curve between 15° and 30° . As the chord of 1 station is always 100 ft, the column of the first station gives instead the *length of arc* subtended by the chord of 100 ft. See §§ 115–119, inclusive, of the text.

TABLE V. Contains the chords of a series of angles varying by half degrees up to 30° for radii varying by 100 to 1000 ft. It shows, therefore, the linear opening between the extremities of two equal lines at any given number of hundred feet from their intersection, when the angle does not exceed 30° . For

any distance exceeding 1000 we have only to add to the value found in that column the value found in the column headed by the excess of distance over 1000 ft. *Conversely*, the table gives the angular deflection required between two equal lines, in order that at a given distance from the point of intersection they may be separated a given amount.

TABLE VI. Contains the values of middle ordinates to long chords of from 2 to 12 stations, for every 10' of degree of curve from 0° to 10° , and of from 2 to 6 stations for every curve from 10° to 20° , at 10-minute intervals. The table may be used, not only to fix the middle point of an arc, but also, in conjunction with the table of long chords, to locate intermediate stations. See §§ 115-119 of the text.

TABLE VII. Gives the correction to be added to *the nominal length of a subchord b* to obtain *the length of the subchord c* when the degree of curve *D* is defined as the angle at the center subtended by a chord of 100 ft.

$$c = b + \text{correction}$$

The value of the correction can be obtained more accurately than given in the table by multiplying the number in column *m* by the number in line *m*.

Example. To find the length of a subchord on a 15° curve when the nominal length is 35 ft. From the table, the correction is 0.09 ft. Hence:

$$c = 35 + 0.09 = 35.09$$

or, more accurately, correction = $(0.286) \times (0.307) = 0.088$. Hence:

$$c = 35 + 0.088 = 35.088$$

TABLE VIII. Contains the middle ordinates of chords varying in length from 16 to 60 ft and for degrees of curve, varying from 1° to 50° . The use of the table is obvious.

TABLE IX. Consists of two parts: The *first* part gives the proper differences in elevation of rails on curves of various degrees from 1° to 50° for velocities varying from 10 to 60 mph. This part of the table is based on equation 324 where the distance between bearing points on rail heads is taken as 4.9 ft. Results are given to thousandths of a foot.

The *second* part, given in inches and fractions, is from the

American Railway Engineering Association Manual. The distance between bearing points of the wheel treads is taken as 4 ft 8½ in. = 4.708 ft.

Ordinarily, the inner rail of the curve is kept at the grade, the outer rail being elevated the full amount e . On some roads, however, the center line defines the grade and then the outer rail is raised $\frac{1}{2}e$, and the inner depressed $\frac{1}{2}e$.

The maximum elevation employed on American railroads is 6 to 8 in. If the elevation of the outer rail for a particular curve and speed exceeds these limits, either the speed or degree of curve must be reduced. In some instances both must be reduced for safe travel.

TABLE X. Contains the values of inches and fractions expressed in decimals of a foot for every 32d of an inch up to 1 ft.

TABLE XI. Contains the radius and its logarithm for the metric curve based on a chord of 20 meters, the deflection angle ranging from $0^{\circ} 10'$ to 10° . It gives also the middle ordinate and tangent offset in meters for one chord, and the degree of curve of the identical curve if laid out in chords of 100 ft by the American method. Numerical values in this table can be derived from Table I by first doubling the deflection angle to get D and then multiplying the values in that table opposite D by 0.20.

TABLE XII. Contains the acreage for right of way 100 ft wide given to tenths of a station or for 10 ft. The values for shorter lengths can be found by interpolating; those for different widths by proportion.

TABLE XIII. Contains the vertical heights through which a train moving at certain velocities would be raised by its own momentum. The table is based on the formula $H = 0.0355V^2$ which includes the effect of the rotative energy of the wheels.

TABLE XIV. Gives the rise of grades in feet per mile and their angle of inclination corresponding to a rise per station (100 ft) varying from 0.01 to 10 ft.

TABLE XV. Contains values of the formula $(\log h - 1) 60384.3$ in which h = reading of the barometer in inches. The inches and tenths of the readings are in the left-hand column, whereas the hundredths are found at the top of the other columns. The *difference* of any two values correspond-

ing to two readings taken simultaneously at any two stations is the difference in elevation in feet of those stations. But the difference in height so found is subject to a correction for temperature given in the next table. See §§ 17 and 18.

TABLE XVI. Contains coefficients of correction for atmospheric temperature, by which the approximate heights obtained by Table XV are to be multiplied for a correction of these heights, which correction is to be added or subtracted according as the coefficient given in the table is marked + or -. See § 19.

TABLE XVII. Contains corrections in feet, required by the curvature of the earth and the refraction of the atmosphere, to be applied to the elevation of a distant object as obtained by a level or transit observation for distances ranging from 300 ft to 10 miles. See § 391.

TABLE XVIII. Contains information for finding the differences in elevation and the horizontal distances in stadia work. The table is based on the formulas: the difference in elevation $= \frac{1}{2}ks \sin 2a + (f+c) \sin a$; and the horizontal distance $= ks^2 \cos a + (f+c) \cos a$.

The quantities in the table under "Diff. Elev." are values of $\frac{1}{2}ks \sin 2a$ where $k = 100$, $s = 1$ and $a =$ the particular vertical angle. With any other values of k and s the product is found by use of the slide rule. The quantities at the foot of the column are values of $(f+c) \sin a$ for three values of $f+c$ (called c in the table). The products for other values of $(f+c)$ are found by interpolating.

Under "Correction to Horizontal Distances" are given $100 - ks^2 \cos^2 a$ for different values of a , when $k = 100$ and $s = 1$. Proper multiplication is made for other values of these quantities.

Example. Angle $2^\circ 46'$; rod reading 2.64; $f+c = 1.1$; and $k = 100$.

Difference in elevation $= 4.82 \times 2.64 + 0.04 = 12.76$.

Correction to horizontal distance for 100 ft $= 0.23$ and for a rod reading of 2.64 it is 2.64×0.23 or 0.6. Correction for $(f+c) \cos a$ is 1.1. Therefore, the horizontal distance $264 - 0.6 + 1.1 = 264.5$.

TABLE XIX. Contains the value of the sun's refraction in terms of the latitude of the place and the hour of the observation. The hour angle indicates the distance of the sun

from the meridian. Three hours indicates either 9 A.M. or 3 P.M. These times are strictly *apparent solar time* which is governed by the motion of the *real sun*. For all practical purposes, however, the time may be considered *standard time* which is kept by the observer's watch.

Complete directions are given in the Nautical Almanac for the computation of declination, and the refraction values are applied to the declinations thus found. North declinations are + and those south are -. The refraction correction is to be added to the former and subtracted from the latter.

This table is used in laying off the proper declination for an observation with the solar attachment.

TABLE XXA gives the lengths of circular arcs of radius = 1. When the tabular value listed for the required central angle is multiplied by the required radius, the exact value of the length of arc is obtained.

Example. To find the length of arc having a radius of 2000 ft and a central angle of $38^{\circ} 22' 47''.8$.

	Angle	Tabular Value
	38°	0.66322512
	$22'$	0.00639954
	$47''$	0.00022786
	$0''.8$	0.00000388
Sum	$38^{\circ} 22' 47''.8$	0.66985640
Arc	$2000 \text{ ft} \times 0.66985640 = 1339.71 \text{ ft}$	

The table also gives the values of minutes and seconds in decimal parts of a degree.

TABLE XXB. Gives the values of arc minus chord ($A - C$) for arcs of radius = 1. When the tabular value listed for the required central angle is multiplied by the radius, the exact difference is obtained. The length of chord can then be computed by subtracting this value from the length of arc.

Also, if desired, the value found in this table can be subtracted directly from the value in Table XXA and the difference multiplied by the radius to obtain the length of chord.

Example. To find the long chord of a curve having a radius of 2000 ft and a central angle of $38^{\circ} 22' 47''.8$.

Angle	Tabular Value	Difference
38° 22'	0.0124408	162
$\frac{47.8}{60} \times 162$	129	
	0.0124537	

$$A - C = 2000 \text{ ft} \times 0.0124537 = 24.9074$$

$$C = \text{arc} - (A - C) = 1339.71 - 24.91 = 1314.80 \text{ ft}$$

or, from Table XXA,

$$\text{Length of arc} = 0.6698564$$

From Table XXB,

$$A - C = 0.0124537$$

$$\text{Difference} = 0.6574027$$

$$C = 2000 \text{ ft} \times 0.6574027 = 1314.81 \text{ ft}$$

TABLE XXI. Contains the values of minutes and seconds expressed in decimals of a degree, for every 10'' of arc, and also for quarter minutes up to 1°.

TABLE XXII. Contains the measurements necessary to lay down a turnout with frogs of given numbers or angles for both a standard and a 3-ft gauge. The distance BF is measured on the rail of the given track from the *heel* of the switch to the *point* of the frog, while af is the chord of the center line of the turnout between the same points. The radius r applies to the center line of the turnout. The distance aF'' is measured on the center line of the straight track from the *heel* of the switch to the point of the middle frog. The length of switch AD should conform to the tabular values unless the throw is to be different from that assumed in the table.

TABLES XXIIA and XXIIB. Contain the recommended standards of the American Railway Engineering Association for frogs and split switches. Offsets are given for locating the lead curves.

TABLE XXIII. Contains the squares, cubes, square roots, cube roots, and reciprocals of numbers from 1 to 1054. Its use may be greatly extended by observing that, if any

number is multiplied by n , its square is multiplied by n^2 , its cube by n^3 , and its reciprocal by $1/n$.

TABLE XXIV. The logarithm of a number consists of two parts, a whole number called the *characteristic*, and a decimal called the *mantissa*. All numbers which consist of the same figures standing in the same order have the same mantissa, regardless of the position of the decimal point in the number, or of the number of ciphers which precede or follow the significant figures of the number. The value of the characteristic depends entirely on the position of the decimal point in the number. It is always one less than the number of figures in the number to the left of the decimal point. The value is therefore diminished by one every time the decimal point of the number is removed one place to the *left*, and *vice versa*. Thus

<i>Number</i>	<i>Logarithm</i>
13840.	4.141136
1384.0	3.141136
138.40	2.141136
13.84	1.141136
1.384	0.141136
0.1384	-1.141136
0.01384	-2.141136
0.001384	-3.141136
etc.	etc.

The mantissa is always positive even when the characteristic is negative. We may avoid the use of a negative characteristic by arbitrarily adding 10, which may be neglected at the close of the calculation. By this rule we have

<i>Number</i>	<i>Logarithm</i>
1.384	0.141136
0.1384	9.141136
0.01384	8.141136
0.001384	7.141136
etc.	etc.

No confusion need arise from this method in finding a number from its logarithm; for, although the logarithm 6.141136 represents either the number 1,384,000 or the decimal 0.0001384, yet these are so diverse in their values that we can never be uncertain in a given problem which to adopt.

Table XXIV contains the [mantissas of logarithms, carried to six places of decimals, for numbers between 1 and 9999, inclusive. The first three figures of a number are given in the first column, the fourth at the top of the other columns. The first two figures of the mantissa are given only in the

second column, but these are understood to apply to the remaining four figures in either column following, which are comprised between the same horizontal lines with the two.

If a number (after the ciphers are cut off at either end) consists of not more than four figures, the mantissa may be taken direct from the table; but by interpolation the logarithm of a number having six figures may be obtained. The last column contains the average difference of consecutive logarithms on the same line, but for a given case the difference needs to be verified by actual subtraction, at least so far as the last figure is concerned. The lower part of the page contains a complete list of differences, with their multiples divided by 10.

To find the logarithm of a number having six figures. Take out the mantissa for the four superior places directly from the table, and find the difference between this mantissa and the next greater in the table. Add to the mantissa taken out the quantity found in the table of proportional parts, opposite the difference, and in the column headed by the fifth figure of the number; also add one tenth the quantity in the column headed by the sixth figure. The sum is the mantissa required, to which must be prefixed a decimal point and the proper characteristic.

Example. Find the log of 23.4275.

For 2342 mantissa is	369587
For diff. 185 col. 7	129.5
For diff. 185 col. 5	9.2

Ans. For 23.4275 log is 1.369726

The decimals of the corrections are added together to determine the nearest value of the sixth figure of the mantissa.

To find the number corresponding to a given logarithm. If the given mantissa is not in the table, find the one next less, and take out the four figures corresponding to it; divide the difference between the two mantissas by the tabular difference in that part of the table, and annex the figures of the quotient to the four figures already taken out. Finally, place the decimal point according to the rule for characteristics, prefixing or annexing ciphers if necessary. The division re-

quired is facilitated by the table of proportional parts, which furnishes by inspection the figures of the quotient.

Example. Find the number of which the logarithm is 8.263927.

First 4 figures 1836 from		8.263927
		263873
	Diff.	54.0
Tabular diff. = 236	$\therefore$ 5th fig. = 2	47.2
		6.80
	6th fig. = 3	7.08

Ans. No. = 0.0183623 or 183,623,000.

The number derived from a six-place logarithm is not reliable beyond the sixth figure.

At the end of Table XXIV is a small table of logarithms of numbers 1 to 100, with the characteristic prefixed, for easy reference when the given number does not exceed two digits. But the same mantissas may be found in the larger table.

TABLE XXV. The logarithmic sine, tangent, etc., of an arc is the logarithm of the natural sine, tangent, etc., of the same arc, but with 10 added to the characteristic to avoid negatives. This table gives log sines, tangents, cosines, and cotangents for every minute of the quadrant. With the number of degrees at the left side of the page are to be read the minutes in the left-hand column; with the degrees on the right-hand side are to be read the minutes in the right-hand column. When the degrees appear at the top of the page, the top headings must be observed; when at the bottom those at the bottom. Since the values found for arcs in the first quadrant are duplicated in the second, the degrees are given from 0° to 180° . The differences in the logarithms due to a change of $1''$ in the arc are given in adjoining columns.

To find the log sin, cos, tan, or cot of a given arc. Take out from the proper column of the table the logarithm corresponding to the given number of degrees and minutes. If there be any seconds, multiply them by the adjoining tabular difference, and apply their product as a correction to the logarithm already taken out. The correction is to be *added* if the logarithms of the table are increasing with the angle or

subtracted if they are decreasing as the angle increases. In the first quadrant the log sines and tangents increase, and the log cosines and cotangents decrease as the angle increases.

Example 1. Find the log sin of $9^{\circ} 28' 20''$.

Log sin of $9^{\circ} 28'$ is	9.216097
Add correction 20×12.62	252
	Ans. 9.216349

Example 2. Find the log cot of $9^{\circ} 28' 20''$.

Log cotan of $9^{\circ} 28'$ is	10.777948
Subtract correction 20×12.97	259
	Ans. 10.777689

To find the angle or arc corresponding to a given logarithmic sine, tangent, cosine, or cotangent. If the given logarithm is found in the proper column, take out the degrees and minutes directly. If not, find the two consecutive logarithms between which the given logarithm would fall, and adopt that one which corresponds to the least number of minutes, which minutes take out with the degrees, and divide the difference between this logarithm and the given one by the adjoining tabular difference for a quotient, which will be the required number of seconds.

With logarithms to six places of decimals the quotient is not reliable beyond the tenth of a second.

Example 1. 9.383731 is the log tan of what angle?

Next less	9.383682 gives	$13^{\circ} 36'$
Diff.	$49.00 \div 9.20 =$	$05''.3$
		Ans. $13^{\circ} 36' 05''.3$

Example 2. 9.249348 is the log cos of what angle?

Next greater	583 gives	$79^{\circ} 46'$
Diff.	$235 \div 11.67 =$	$20''.1$
		Ans. $79^{\circ} 46' 20''.1$

These rules do not apply to the first two pages of this table (except for the column headed cosine at the top), because here the differences vary so rapidly that interpolation made by them in the usual way will not give exact results.

On the first two pages, the *first* column contains the number of seconds for every minute from $1'$ to 2° ; the minutes are given in the *second*, the log sin in the *third*, and in the *fourth* are the last three figures of a logarithm which is the difference between the log sin and the logarithm of the number of seconds in the first column. The first three figures and the characteristic of this logarithm are placed, once for all, at the head of the column.

To find the log sin of an arc less than 2° given to seconds. Reduce the given arc to seconds, take the logarithm of the number of seconds from the table of logarithms, and *add* to this the logarithm from the fourth column opposite the same number of seconds. The sum is the log sin required.

The logarithm in the fourth column may need a slight interpolation of the last figure, to make it correspond closely to the given number of seconds.

Example 1. Find the log sin of $1^\circ 39' 14''.4$.

$$\begin{array}{rcl} 1^\circ 39' 14''.4 = 5954''.4 & & \log 3.774838 \\ & & \text{add } (q-l) \ 4.685515 \\ & & \hline \end{array}$$

Ans. log sin 8.460353

Log tangents of small arcs are found in the same way, only the last four figures of $(q-l)$ being taken from the *fifth* column.

Example 2. Find the log tan of $0^\circ 52' 35''$.

$$\begin{array}{rcl} 52' 35'' = (3120'' + 35'') = 3155'' & \log 3.498999 \\ & \text{add } (q-l) \ 4.685609 \\ & \hline \end{array}$$

Ans. log tan 8.184608

To find the log cotangent of an angle less than 2° given to seconds. Take from the column headed $(q+l)$ the logarithm corresponding to the given angle, interpolating for the last figure if necessary, and from this *subtract* the logarithm of the number of seconds in the given angle.

Example 1. Find the log cotan of $1^{\circ} 44' 22''.5$.

$$\begin{array}{r}
 6240'' + 22''.5 = 6262.5 \\
 \begin{array}{r}
 q+l \ 15.314292 \\
 \log \ 3.796748 \\
 \hline
 \end{array} \\
 \text{Ans.} \quad 11.517544
 \end{array}$$

These two pages may be used in the same way when the given angle lies between 88° and 92° , or between 178° and 180° ; but, if the number of degrees be found at the *bottom* of the page, the title of each column will be found there also; and if the number of degrees be found on the *right-hand* side of the page, the number of minutes must be found in the right-hand column, and, since here the minutes increase upward, the number of seconds on the same line in the first column must be *diminished* by the odd seconds in the given angle to obtain the number whose logarithm is to be used with $(q \pm l)$ taken from the table.

Example 2. Find the log cos of $88^{\circ} 41' 12''.5$.

$$\begin{array}{r}
 4740'' - 12''.5 = 4727.5 \\
 \begin{array}{r}
 (q-l) \ 4.685537 \\
 \log \ 3.674631 \\
 \hline
 \end{array} \\
 \text{Ans.} \quad 8.360168
 \end{array}$$

Example 3. Find the log tan of $90^{\circ} 30' 50''$.

$$\begin{array}{r}
 1800'' + 50'' = 1850'' \\
 \begin{array}{r}
 q+l \ 15.314413 \\
 \log \ 3.267172 \\
 \hline
 \end{array} \\
 \text{Ans.} \quad 12.047241
 \end{array}$$

To find the arc corresponding to a given log sin, cos, tan, or cotan which falls within the limits of the first two pages of Table XXV. Find in the proper column two consecutive logarithms between which the given logarithm falls. If the title of the given function is found at the top of that column, read the degrees from the top of the page; if at the bottom, read from the bottom.

Find the value of $(q-l)$ or $(q+l)$, as the case may require, corresponding to the given log (interpolating for the last figure if necessary). Then, if q = given log and l = log of number of seconds n in the required arc, we have at once $l = q - (q-l)$ or $l = (q+l) - q$, whence n is easily found.

Find in the first column two consecutive quantities between which the number n falls, and, if the degrees are read from the *left-hand* side of the page, adopt the *less*, take out the minutes from the second column, and take for the seconds the difference between the quantity adopted and the number n . But, if the degrees are read from the *right-hand* side of the page, adopt the *greater* quantity, take out the minutes on the same line from the right-hand column, and for the seconds take the difference between the number adopted and the number n .

Example 1. 11.734268 is the log cot of what arc?

$q+l$		15.314376
q		11.734268
$\therefore n =$	3802'' ⁸	3.580108
For 1° adopt	3780.	giving 03'
Difference	22'' ⁸	

Ans. 1° 03' 22''⁸ or 178° 56' 37''².

Example 2. 8.201795 is the log cos of what arc?

$q-l$		4.685556
q		8.201795
$\therefore n =$	3282'' ⁸	3.516239
For 89' adopt	3300.	giving 05'
Difference	17'' ²	

Ans. 89° 05' 17''² or 90° 54' 42''⁸.

TABLE XXVI. Contains logarithmic versed sines and external secants for every minute of the quadrant, with the differences of the same corresponding to a change of 1 second in the arc or angle. Interpolation for seconds is made in the same manner as with log sines of the preceding table, except on the first two pages. For angles less than 4° the differences vary so rapidly that interpolation by direct proportion will not give exact values.

On the first two pages the column headed $q-2l$ contains the difference between the log versed sine (or log ex secant)

of an arc and *twice* the logarithm of the number of seconds in the same arc. The characteristic, and first three decimals (9.070) are common to all the logarithms in these columns up to $3^{\circ} 19'$ for log vers sines, where it changes to (9.069), as shown at the foot of the column; and up to 4° for log ex secants, where it changes to (9.071). At the point of change a cipher is replaced by the mark * to call attention.

To find the log vers sin, or log ex sec of an angle given to seconds. Reduce the angle to seconds, take the logarithm of this number, multiply it by 2, and add the product to the logarithm in the column ($q-2l$) found opposite the given angle. The log ($q-2l$) should be corrected by interpolation for the fractional part of a minute in the given angle.

Example. What is the log ex secant of $2^{\circ} 14' 43''.7$?

$$2^{\circ} 14' 43''.7 = 8040'' + 43.7 = 8083''.7 \quad \log 3.907610$$

$$\begin{array}{r} 2l \quad 7.815220 \\ (q-2l) \quad 9.070398 \end{array}$$

$$\text{Ans. } \therefore q \quad 6.885618$$

To find the arc corresponding to a given log vers, or log ex sec. Find in the column of log vers, or log ex sec the two values between which the given log falls, and take out from the column ($q-2l$) the logarithm corresponding to the given log (interpolating for the value of the last figure if necessary). Subtract this from the given logarithm and divide by 2. The quotient is the logarithm of the number of seconds in the required arc.

Example. 7.344728 is the log vers of what arc?

$$\begin{array}{r} 3^{\circ} 48' + \quad \quad \quad q \quad 7.344728 \\ \quad \quad \quad (q-2l) \quad 9.069960 \\ \hline \quad \quad \quad 2) 8.274768 \\ \hline 13720''.9 \quad \quad \quad \therefore l \quad 4.137384 \\ 13680. \end{array}$$

$$\text{Ans. } 3^{\circ} 48' 40''.9$$

To find the log ex sec of an arc greater than 88° given to seconds. Take from the column ($q+l$) the logarithm corresponding to the given arc, interpolating for the fraction of a minute. From this subtract the logarithm of the number of seconds in the *complement* of the given arc.

Example. What is the log ex sec of $88^\circ 24' 20''.5$?

For $88^\circ 24'$	$q+l$	15.302183
Correction $129 \times \frac{20.5}{60} =$		44
	$q+l$	15.302227
Comp: $88^\circ 24' 20''.5 = 5739''.5$		log 3.758874
	<i>Ans.</i>	log ex sec 11.543353

To find the angle corresponding to a given log ex sec when the angle is greater than 88° . Find in the table the two consecutive log ex secants between which the given one falls, then find by interpolation the value of the log ($q+l$) corresponding to the given log ex sec, and subtract the latter from it. The difference will be the logarithm of the number of seconds in the *complement* of the required angle, which is then easily found.

Example. 11.924368 is the log ex sec of what arc?

Given log ex sec	11.924368	
Next less	11.918290	$q+l$ 15.309225
Diff.	6078	
Correction = $\frac{9352-9225}{29141-18290} \times 6078 =$		71
		$q+l$ 15.309296
Given log ex sec		11.924368
$0^\circ 40' 26''.2 = 2426''.2$	$\therefore$	log 3.384928

Ans. $89^\circ 19' 33''.8$.

TABLE XXVII. Contains natural sines and cosines, to seven places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly pro-

portional to the difference of consecutive values in the table: positive for sines, negative for cosines.

TABLE XXVIII. Contains natural tangents and cotangents to seven places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly proportional to the difference of consecutive values in the table: positive for tangents, negative for cotangents.

TABLES XXIX and XXIXA. Contain natural versed sines, external secants, secants, and cosecants to seven places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly proportional to the difference of consecutive values.

TABLE XXX. Contains the number of cubic yards contained in prismoids of various side slopes, bases, and depths, as indicated by the title and the numbers in the first column. Each prismoid is supposed to have a uniform level cross section throughout. These tables are chiefly useful in making up preliminary estimates from the profile, or in other cases where only approximate results are required. For monthly and final estimates more elaborate tables are required, such as are described in §§ 288-291 of the text.

To make an approximate estimate of quantities from a profile by use of Table XXX. Select the proper column for base and slopes, and, if the outline of a cut on the profile is roughly a four-sided figure, stretch a fine silk thread over the surface line to average it, note the depth from thread to grade line midway of the cutting, and multiply the tabular number opposite this depth by the average length of the cutting in stations of 100 ft. (By average length is meant the half sum of the length of the grade line in the cutting and of so much of the surface line as is covered by the thread.) If the area of a cutting as seen on the profile is approximately triangular, stretch an averaging line over each incline, note the depth from the intersection of these lines to grade, and multiply the tabular number opposite this depth by one-half the length of the cut measured on the grade line in stations. The resulting quantities will be slightly in excess if the ground is level transversely, but may be too small if the transverse slope is steep, and cutting on the center line is small. In general, they furnish a good approximation. Quantities in embankments may, of course, be found similarly. A cut or

fill may be divided on the profile into several portions and the contents of each portion found separately if preferred.

The content of a prismoid, level transversely, but having different end depths, may be found correctly by this table thus: Add together the quantities opposite each end depth and four times the quantity opposite the half sum of the depths, multiply the sum by the length in feet, and divide by 600.

TABLE XXXI. The volume of a triangular prism is equal to the product of the area of the base and the altitude. This, in cubic yards, for a length of 50 ft, is expressed by the formula, $S = (50/54)ba$, where b and a are the base and altitude of the triangular section. Any end area of a section of earthwork, whether three-level or irregular, may be divided into a number of triangles, and the total volume of the solid between the sections may be considered as composed of prisms with these triangles as bases. The mean area volume of a solid for 100 ft in length will be the sum of the two 50-ft volumes. An example will illustrate the use of the table.

Example. Given the following notes:

Sta. 28	$\frac{16.0}{+4.0}$	+2.4	$\frac{11.8}{+1.2}$
Sta. 27	$\frac{19.0}{+6.0}$	+3.0	$\frac{13.6}{+2.4}$

Base 20 ft, slope $1\frac{1}{2}$ to 1.

Two methods might be used for the work. First, where the section is divided into four triangles, and, second, where the area is composed of two triangles less a third triangle which is formed by prolonging the side slope lines to their intersection. The former method will be used.

The volume for station 27 for length 50 ft is

$$\frac{50}{54}(3.0)(19.0+13.6) + \frac{50}{54}(6.0+2.4)(10)$$

Opposite height	3.0	under 3	take	10×8.333	=	83.330
		2		1×5.556	=	5.556
		6		$\frac{1}{10} \times 16.667$	=	1.667

Also

Opposite height 8.4 under 1 take $10 \times 7.778 = 77.780$

$\therefore$ Total volume for length 50 ft = 168.333

Similarly, the volume for station 28 for length 50 ft is

$$\frac{50}{54}(2.4)(16.0+11.8) + \frac{50}{54}(4.0+1.2)(10) = 109.927$$

The work may be somewhat shortened by not strictly observing the terms "height" and "width," since $(50/54)(32.6)(3.0)$ is the same in value as the expression given previously for station 27. This is obtained by entering the table once, considering 32.6 as the height, and 3.0 as the width.

The mean area volume will then be

$$168.333 + 109.927 = 278.26, \text{ or } 278.3 \text{ cu yd}$$

The prismoidal correction may be applied to this result, thus giving the prismoidal volume. The explanation of the method of finding this correction is given below.

TABLE XXXII. This table gives the correction to be applied to the mean area volume to give the prismoidal volume. The table is based on the formula,

$$C = \frac{1}{3.24}(d-d')(D-D')$$

where d and d' are the center heights, and D and D' the distances between slope stakes at two adjacent stations.

If the same data as given under the explanation of Table XXXI is used, the value of the correction is

$$C = \frac{1}{3.24}(3.0-2.4)(32.6-27.8) = \frac{1}{3.24}(0.6)(4.8)$$

From Table XXXII find

$$\text{Opposite } D-D', 4.8 \text{ under } 6 \text{ take } \frac{1}{10} \times 8.889 = 0.9$$

The mean area volume from the same example was 278.3 cu yd. The prismoidal volume will then be $278.3 - 0.9 = 277.4$.

The volume for any other distance between sections may be found by taking the proper percentage of the volume for

100 ft distance, the multiplication being made after the application of the prismoidal correction.

TABLE XXXIII. Contains the recommendations of the American Railway Engineering Association on minimum lengths of spirals for various speeds and degrees of curve.

TABLE XXXIV. This table exhibits the features of the original spiral from which others may be derived. The degree of curve is assumed to vary with each chord, and from this the central spiral angle up to any point is easily derived, and also the inclination of any chord to the main tangent drawn through S as meridian.

The coordinates, x and y of any spiral point, referred to S as an origin, are obtained by summation of departures and latitudes of the intervening chords. These are given with great precision, so that their continuous summation may not lead to any error in the final result.

Finally, the deflection angle from the tangent at S to any spiral point is found by dividing x by y for that point, giving the tangent for the deflection. All these results are tabulated, as also the radius corresponding to the degree of curve, the chord length being 100 ft, as with an ordinary circular curve. These deflections remain the same for any spiral whatever. The variation is made in the length of the chord, and the values of x , y , and R_s vary directly with the chord length. The value of D_s is derived from R_s . This table is made the basis of the tables which follow.

TABLE XXXV. This gives the list of deflections to each of the spiral points, not only from S (as in the preceding table), but also from each one of the 20 other spiral points in the system.

TABLE XXXVI. This gives a series of spirals of assumed chord length from 10 to 50, with the corresponding values of D_s , y , and x . In any case only so many chords will be used as will lead up to (and not beyond) the selected degree of curve which is to follow the spiral. The terminal point L of any spiral indicates the values of x and y to be used in connection with it.

TABLE XXXVII. This table gives certain trigonometric functions of the spiral angle s for convenient reference in using spiral formulas.

TABLE XXXVIII. This table, as a companion to XXXVI,

gives the spiral tangents and long chord for the same set of spirals and also the coordinates p and q from S . Read the note at the head of the table.

TABLE XXXIX. Gives a selection of circular curves, varying in degree from $1^{\circ} 40'$ to 35° , suitable spirals to be used with each, and also the coordinates p and q from S of the point A' where the particular curve would meet a parallel tangent. Generally there is considerable choice in the length of spiral.

TABLE XL. Exhibits a series of special cases where it is required to replace an existing simple curve by another with spirals so chosen that the length of the track shall not be sensibly altered. The middle offset h is given; also x , and the distance $d = AS$, from old P.C. to P.S., and the new degree of curve D' .

The series embraces curves of 2° , 4° , 8° , and 16° , and central angles from 10° to 80° , inclusive, and will be found very useful in solving problems of this sort.

TABLE XLI. Contains concise statements of such geometrical truths as are applicable to the various discussions in this volume. References are given to Davies' "Geometry," in which the demonstrations of the propositions may be found.

TABLE XLII. Contains all the formulas necessary to the solution of any plane triangle; also, a select list of miscellaneous formulas. A few formulas with respect to the versed sine and external secant are new.

TABLE XLIII. Contains a list of the more important formulas derived in the text. A large number of special formulas on simple curves are given, for which no derivations are included. The notation is the same as that used in the text.

TABLE XLIV. Contains a variety of useful numbers and formulas. The logarithms are here given to seven places of decimals.

TABLE XLV. Deflections for the ten-chord spiral. Transit at S . These deflections are computed by equation 264, the coordinates of the several points being used, and are rigidly correct. They are independent of the length of spiral but depend on the spiral angle S . When the required value of S is not found in this table, interpolation may be made. The first deflection is always S divided by 300.

TABLE XLVI. Coefficients for deflections from local tangent at any point. At whatever chord point the transit is set, the vernier reads zero on the local tangent through that point. For any other chord point multiply the first deflection i_1 (Table XLV) by the coefficients (Table XLVI) found in the column of the same number as the transit point. When the product is for a point more than five points from the transit, it is subject to a small correction found in Table XLVII. This correction is on the line of the spiral angle S and in the column of the point observed, *counting from the transit as zero*. The correction is *minus* for sights made toward L and *plus* for sights made toward S .

By the use of the tenth column a series of deflections are obtained which, after correction, serve to locate the spiral from L to the tangent at S . This method is more convenient than that given in § 249.

Example 1. Given a spiral of 360 ft connecting with a 20° curve, to find the deflections from the common tangent at L' .

By equation 257, $S = 36'$, $i_1 = 7.2'$, $c = 36$ ft.

Multiply i_1 by coefficients in last column of Table XLVI for these deflections, the first five of which, being small, need no correction. The last five products and their corrections (from Table XLVII) and the required deflections are as follows:

Point	Product	Correction	Deflection
4	$17^\circ 16.8'$	+ 00.1'	$17^\circ 16.9'$
3	19 19.2	+ 00.3	19 19.5
2	21 07.2	+ 00.6	21 07.8
1	22 40.8	+ 01.2	22 42.0
S'	24 00.0	+ 02.3	24 02.3

Note that point 4 is the sixth sight from L' ; hence, the correction is found in column 6, line of 36° . The others follow.

Example 2. The same spiral with transit at point 8.

There is no correction prior to point 2, which is the sixth from the transit.

Point	Product	Correction	Deflection
2	$12^\circ 57.6'$	+ 00.1'	$12^\circ 57.7'$
1	14 16.8	+ 00.3	14 17.1'
S'	15 21.6	+ 00.6	15 22.2

Example 3. The same spiral with transit at point 3.

Find coefficients in column 3, Table XLVI. Here point L is the seventh from the transit, and looking toward L ; hence,

the correction is *minus* 00.3. The others, after point 9, need no correction.

Point	Product	Correction	Deflection
L	13° 26.4'	— 00.3'	13° 26.1'
9	10 48.0	— 00.1	10 47.9

TABLE XLVII. Corrections in minutes for the larger deflections. Equation 261 is convenient for computing a deflection i , but since it is an approximate formula, the result is subject to a small correction when it exceeds 5', or when the point observed is more than five chord points from the transit. Corrections are given to two decimal places, but only the first decimal usually need be quoted. The application of these corrections has been explained in connection with Table XLVI. Observe that in Table XLVI the columns are numbered from the tangent point S , but in Table XLVII they are numbered from the position of the transit.

TABLE XLVIII. Spiral parts for given degrees of curve. This table presents a list of 20 curves, between 1° and 20°, inclusive, combined with 16 to 28 spirals for each curve, giving for each length of spiral, the spiral angle S , the final coordinates X and Y , the long chord C , and also the coordinates p and q of A' on the circular curve. When a selection of curve and spiral can be made from this table, these quantities can be taken out at once.

TABLE XLIX. Coefficients of L for spiral parts for given values of S . Spirals having the same central angle S are similar, whatever be their length, and so their parts are proportional to their length. Either part divided by the length gives a coefficient for finding that part in terms of L when S is given. By equation 257, $L = 200S/D$. If S is not given exactly in the table the required coefficient may be found by interpolation.

The coordinates p and q , being functions of both spiral and curve, require two coefficients to express their value, as shown in the table. But, if X and Y are already known, it will be more convenient to find p and q by equation 268.

TABLE L. Contains the radius of curve according to the *arc* definition for curves varying by 10' from 0° 30' up to 120° 0'. Also the deflection for 1 ft of arc, together with the deflections for two other lengths of arcs, the particular ones chosen depending on the sharpness of the curve. The

deflection for the 100-ft arc is not given since it is one-half D . The chord lengths are also given for 100-ft arcs and for two other shorter arcs. The *length of arc which is recommended* is one where the arc and its chord do not differ materially from each other. By an inspection of the table it would seem that 100-ft arcs might be used for curves up to 7° ; 50-ft arcs up to 18° ; 25-ft arcs up to 32° ; and then 10-ft arcs upward.

For the sake of completeness, the theory of the table is based on the following:

In highway work, the degree of curve is the central angle subtended by an *arc* of 100 ft. And, second, the *length of curve* is measured along the *arc* instead of along *chords* as in railroad work.

Let D = the degree of curve and R = the radius. Then a simple curve is a part of a whole circle, and we have the proportion,

$$D:360^\circ::100:2\pi R$$

or

$$D = \frac{100(360^\circ)}{2\pi R} = \frac{5729.58}{R}$$

and

$$R = \frac{5729.58}{D}$$

In other words, the *radius* varies *inversely* with the *degree of curve*.

TABLE LI. Contains material similar to that in Table L, but for curves with radii given in feet. Many highway commissions use only an even foot radius curve and do not use the term "degree of curve." The recommended length of arc with its accompanying chord may be found by inspection of the table.

TABLE LII. This table is the reverse of Table XXA. It is based on the following: Let a° = the central angle (in degrees) of an arc whose radius and length are R and l , respectively.

Then,

$$a^\circ = \frac{57.2957795l}{R}$$

If $a' =$ the central angle in minutes,

$$a' = \frac{60(57.2957795)l}{R} = Kl$$

Certain values of the radius are assumed as shown in the table, and the corresponding values of K are found.

Example. To find the central angle for an arc of 75 ft on a curve of 150-ft radius.

From the table, the coefficient K for a curve with radius 150 ft is 22.9183118. The central angle in minutes for a 75-ft arc will be $75(22.9183118) = 1718.873385' = 28^{\circ} 38' 52''.4$.

Check. The coefficient for angle $28^{\circ} 38' 52''.4$ is found from Table XXA.

For 28°	0.4886922
38'	0.0110538
52''	0.0002521
0.4''	0.0000019
Total	0.5000000

and this multiplied by 150 gives the length of arc as 75.00.

Table 19 in "Highway Curves" by Howard Chapin Ives, one of the authors of this text, gives this coefficient with one less addition.







